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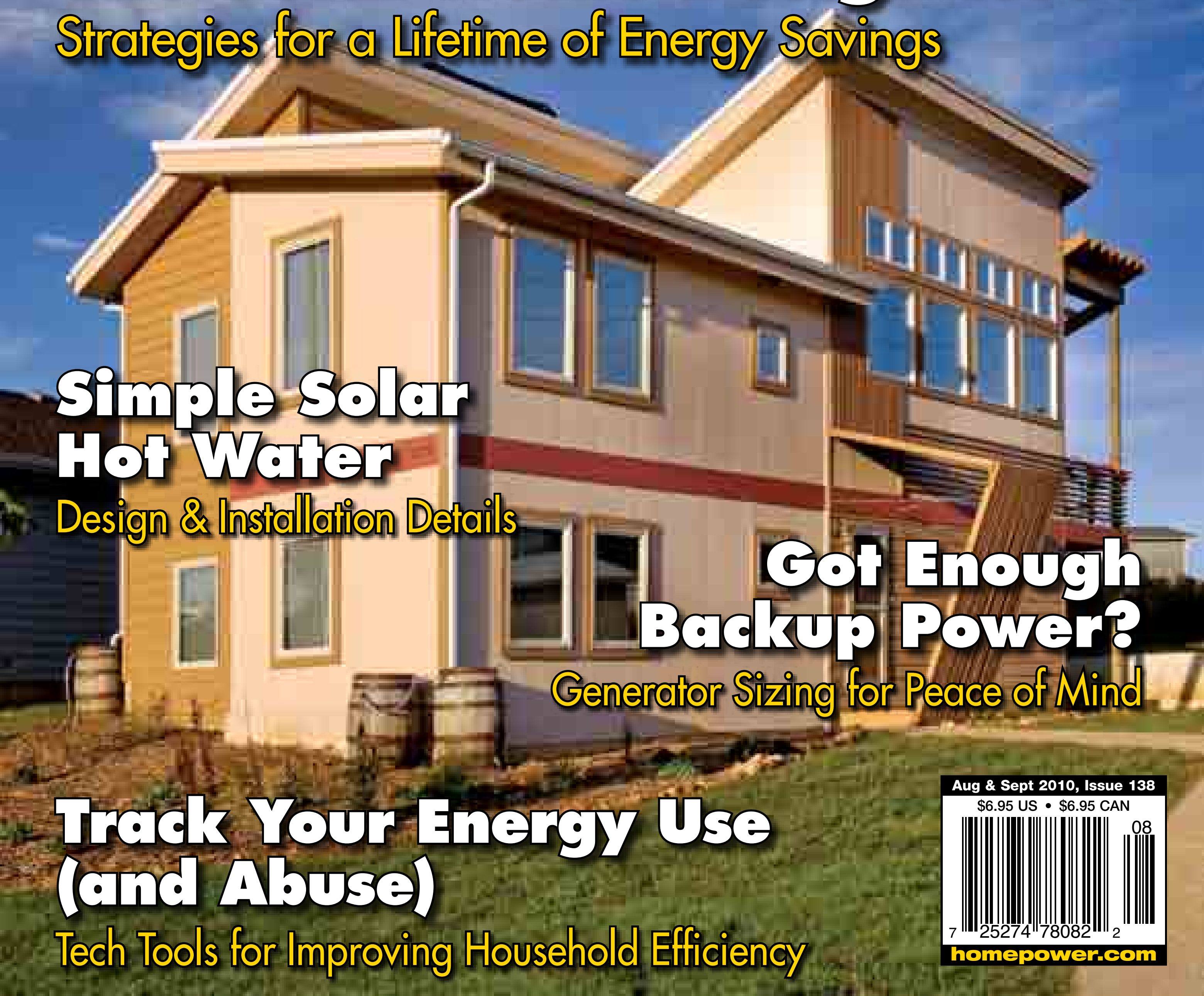

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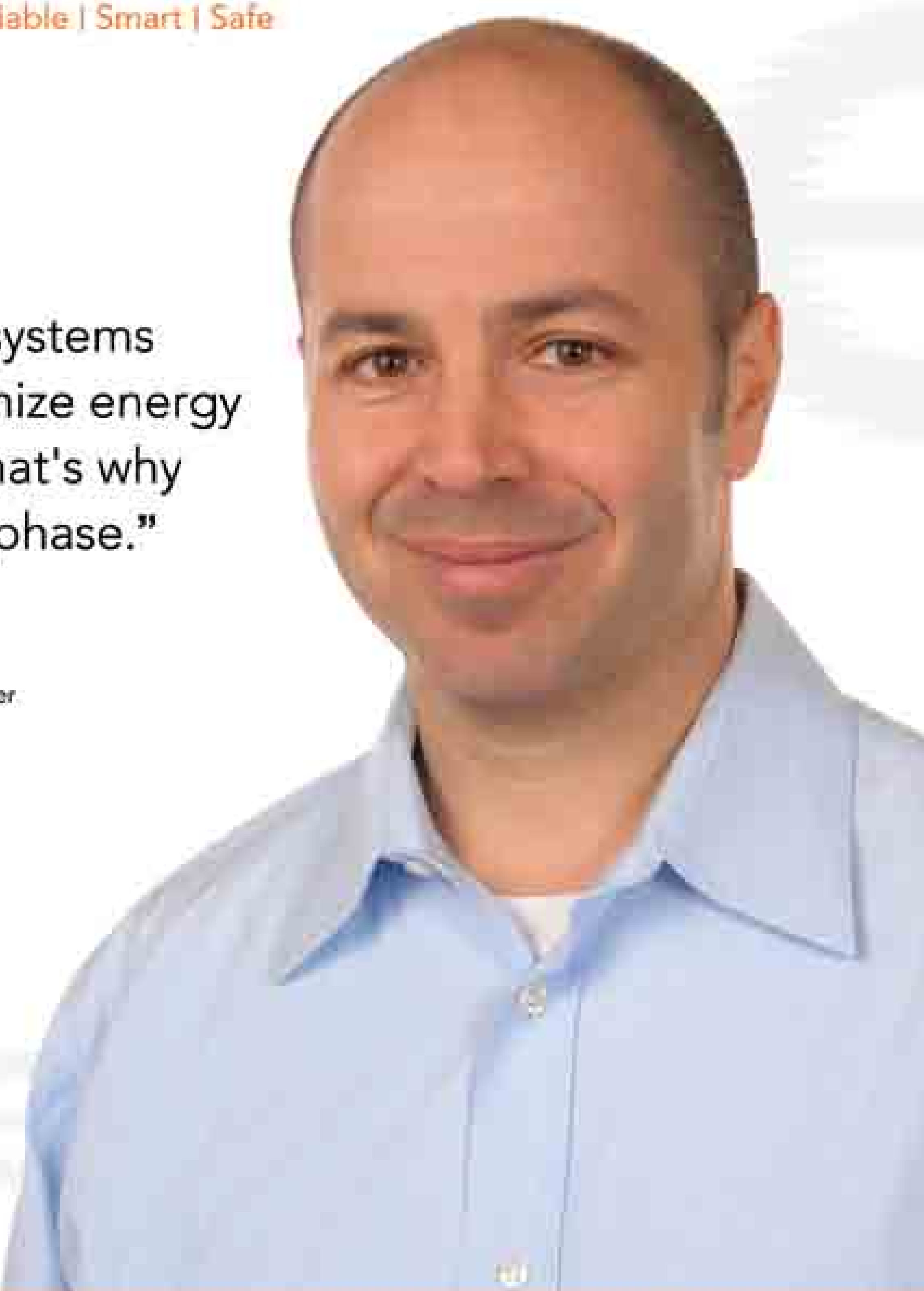

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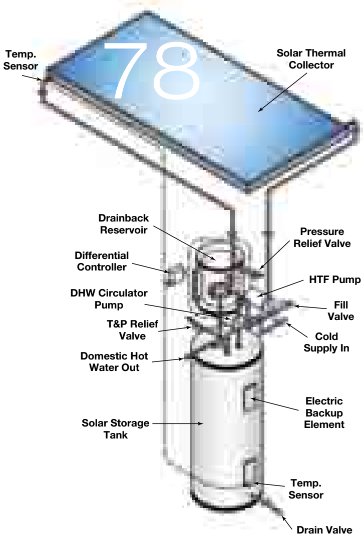

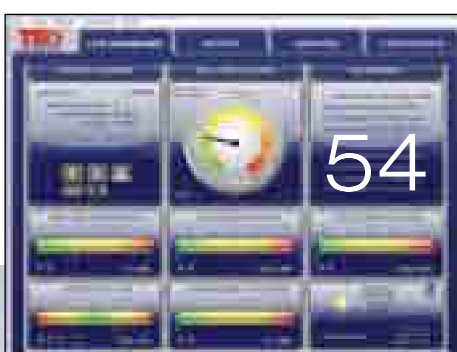

Top to bottom: Courtesy www.passivehouse.us (2); www.aetsolar.com; www.arttec.net; www.sunsensesolar.com

Special Solar Design Issue

More Features

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august & september 2010

Up Front

More Features

Bottom: Courtesy Traci Sooter; top: www.aillc.biz

On the Cover

The LEED Platinum Certified home in Springfield, Missouri, designed and built as a joint project between Habitat for Humanity and Drury University School of Architecture students.

Photo courtesy www.aillc.biz

In Back

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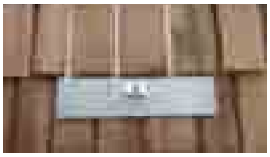
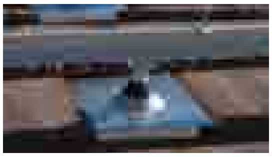


CURVED TILE

FLAT TILE



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The Solar Spill

There are unintended consequences from each decision and act we make—and the latest oil spill catastrophe in the Gulf is just one example of how our collective choices in energy consumption have a huge impact. With agribusiness, mass-produced homes, and other "modern" conveniences, these choices go beyond what car we drive or the recycled products we buy. Cheap oil has made possible the kinds of food we eat, the plastic it's wrapped in, and the houses we come home to.

While we each own a part of this spill, we can move on to take an active role in preventing another catastrophe by taking individual ownership of the part we play. *How* we can do this is a message that *Home Power* has been delivering for more than two decades: first, reduce your need; then switch to renewables.

Renewable energy adopters know how to live well with less, whether it is by capturing solar energy through passive solar design to reduce a home's heating loads or actively producing electricity with photovoltaic modules, a wind genny, or a microhydro turbine. You'll find all that and more in this issue, which delves into the concepts of passive solar homebuilding; discusses how you can retrofit your existing home for passive solar gain; profiles tools for understanding and changing your electricity consumption; instructs on the finer points of optimizing grid-tied array sizing; and more.

Each day, the sun delivers enough energy to support all life on our planet. We can't escape the Earth-friendly solar energy that spills upon us each and every day—nor do we need to escape it. This free, abundant power has the grace to rival every energy source we know.

—Rachel Connor, for the *Home Power* crew

Think About It...

"We, as a nation, have to see that neither our energy independence nor our environmental and health safety are served by our addiction to fossil fuels."

—Kristine Stratton, www.waterkeeper.org

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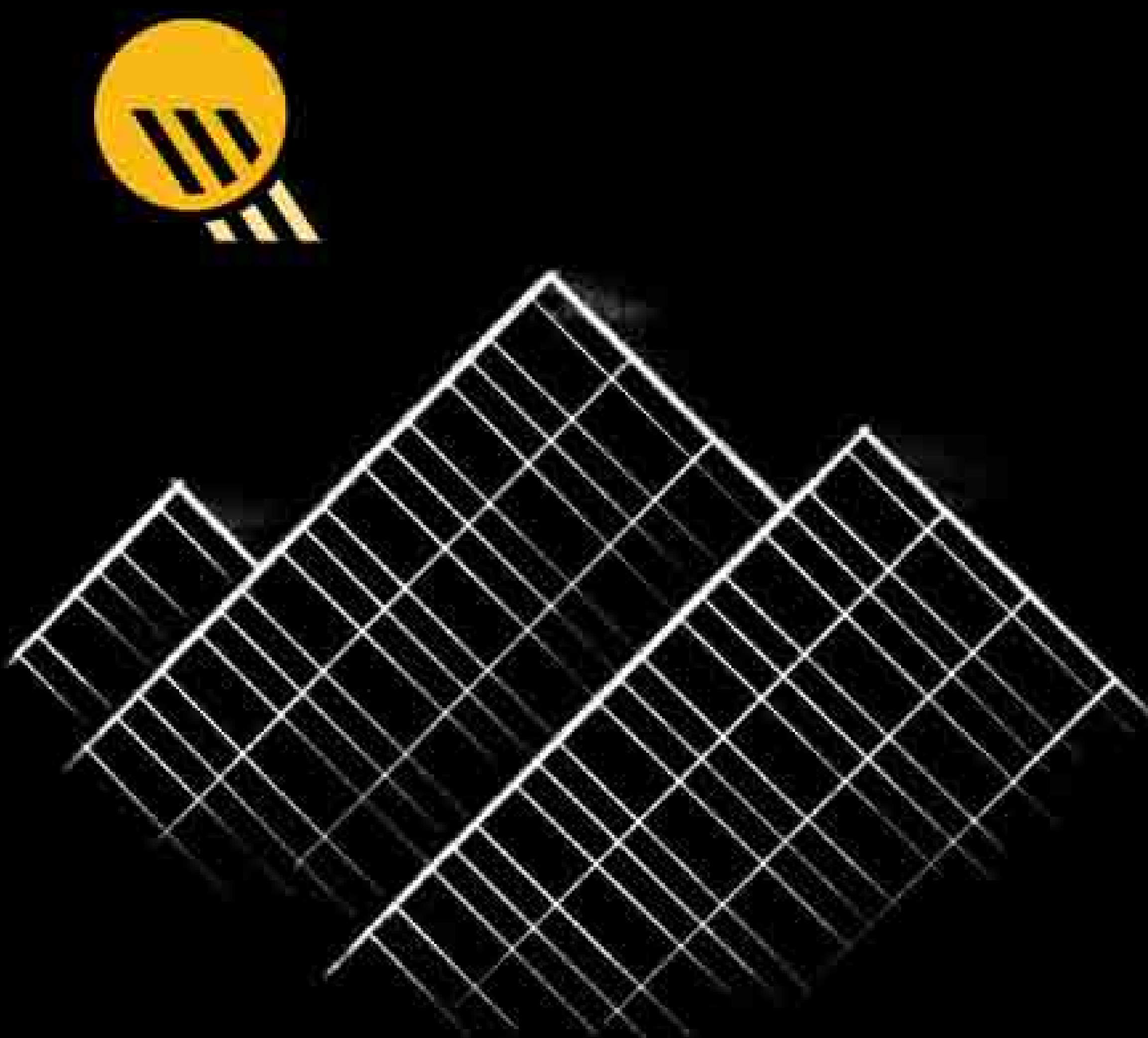
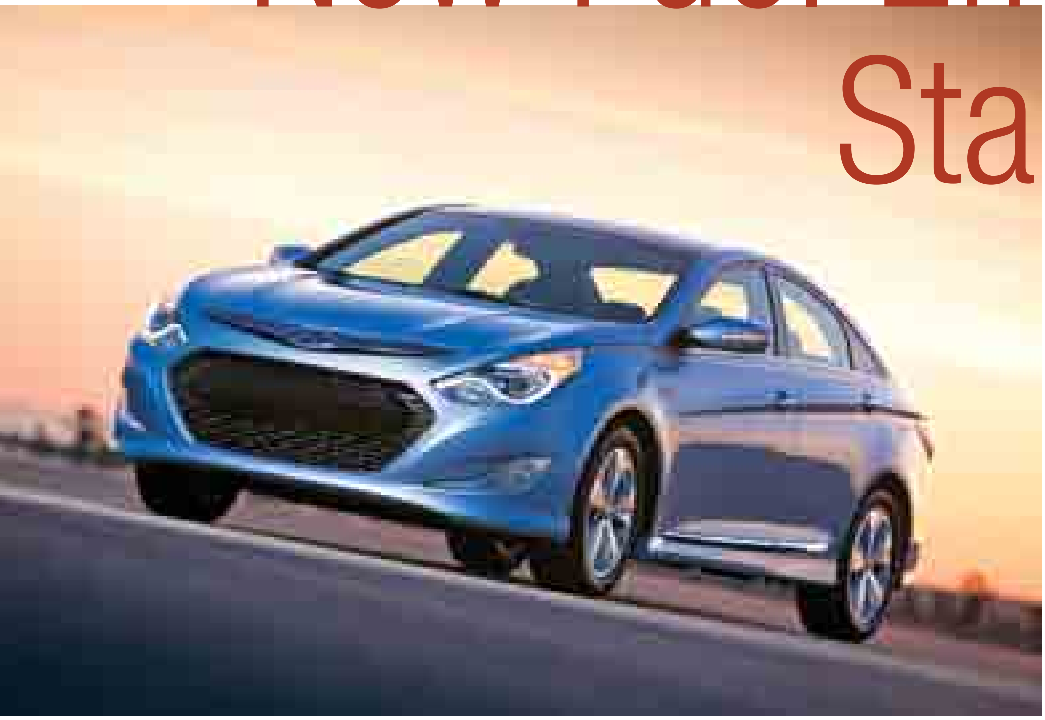


New Fuel Efficiency Standards


Courtesy www.hyundaiusa.com

Left: The Hyundai Sonata Hybrid is expected to achieve 37 mpg in the city and 39 mpg on the highway.

Below: Two-seat Honda CR-Z EX hybrid manual transmission models are anticipated to achieve an EPA-estimated fuel economy rating of 31 city or 37 highway mpg.

Americans will have to pay more for cars and trucks, but they'll save at the pump under new fuel economy rules that aim to cut pollution and curb dependence on oil.

The new rules, jointly written by the U.S. Department of Transportation and the Environmental Protection Agency, set tougher requirements for fuel efficiency and establish the first-ever standards for greenhouse gas emissions from vehicles. The new rules reflect a May 2009 agreement among government administrators, auto executives, and environmental advocates. The announcement comes as efforts to contain the oil spill in the Gulf of Mexico continue.

Starting with 2012 model-year vehicles, U.S. automakers are required to improve fleet-wide fuel economy and reduce greenhouse gas emissions by approximately 5% every year. By 2016, new passenger cars and light trucks sold in the United States must get an average of 35.5 miles per gallon—up from 27.5 mpg currently.

The DOT and EPA estimate that the new requirements will save the average buyer of a 2016 model-year car more than $3,000 in fuel costs at projected prices over the life of the vehicle. However, implementing the necessary changes to the vehicles and manufacturing operations will add up to $1,000 to the cost of the average new car by 2016, according to industry estimates.

"These historic new standards set ambitious, but achievable, fuel economy requirements for the automotive industry that will also encourage new and emerging technologies," said Transportation Secretary Ray LaHood.

The new federal rules accelerate goals set by a 2007 law that mandated a 35-miles-per-gallon average by 2020 and bring the benefits of California's landmark clean car

standards to the entire nation. The California standards, set in 2004, were adopted by 13 other states and the District of Columbia.

The Natural Resources Defense Council estimates that the new standards will cut oil consumption by 1.3 million barrels a day and slash global warming pollution by more than 220 million metric tons in 2020, plus save consumers $65 billion at the pump.

"These historic standards will help consumers, automakers, and the planet," said Roland Hwang, NRDC Transportation Program Director. "Clean, efficient cars will put us on the road to safely reducing our dangerous dependency on foreign oil."

While many environmental groups have applauded the federal government for taking a step forward, some would have preferred more aggressive measures.

"Despite the increase, the rule will leave the United States far behind the fuel efficiency that European and Japanese cars achieve today, at close to 44 mpg and 43 mpg respectively," said Kierán Suckling, executive director of the Center for Biological Diversity. "Until U.S. standards are improved as our laws require, the U.S. auto industry will continue to lag behind its international rivals."

—Kelly Davidson

Courtesy www.honda.com

Buyer Beware:
Bogus Energy Star Certifications

Covert testing conducted by the U.S. Government Accountability Office (GAO) found that the Energy Star (ES) program is vulnerable to fraud and abuse. Using four phony manufacturing companies and fictitious identities, the office obtained ES certification for more than a dozen bogus products—the majority of which received approval and were listed on the ES Web site within days of submission.

The DOE and EPA, who jointly manage the program, acted fast, taking immediate measures to close self-certification loopholes and beef up verification requirements.

Among the bogus products that earned ES certification were a gas-powered alarm clock, a geothermal heat pump that claimed to be 20% more efficient than similar qualified products, and an "air purifier" that was essentially a space heater with a feather duster and fly strips attached.

Auditors found that there was little scrutiny of exaggerated claims of efficiency. According to the report, "The current process for becoming an Energy Star partner and certifying specific products as Energy Star compliant provides little assurance that products with the Energy Star label are some of the most efficient on the market."

News of the findings comes on the heels of several highly publicized investigations and reports that have identified weaknesses of the 18-year-old ES program. Over the past year, the DOE and EPA have been taking steps to address issues with product compliance and enforcement. However, in response to this latest investigation, the two agencies issued a joint statement calling the previous measures they have taken "simply insufficient."

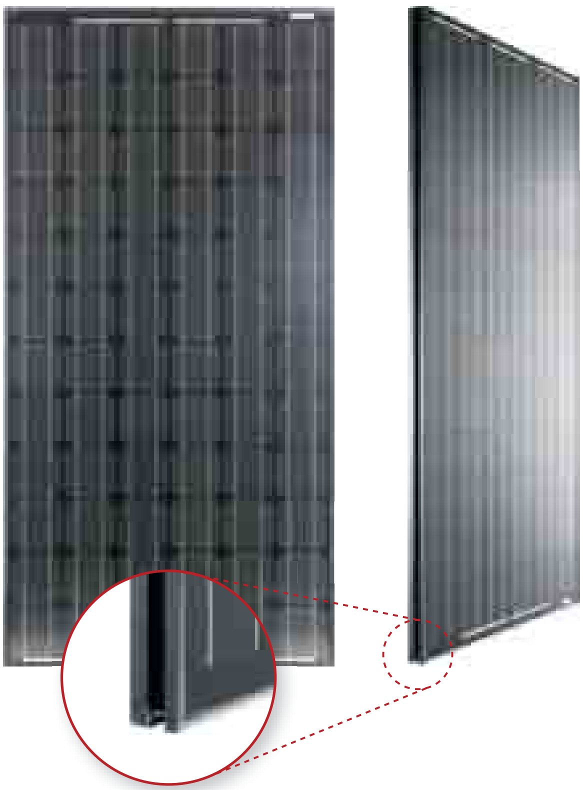
Immediately following the report's release, ES administrators set in motion "a rapid 180-degree shift in the way manufacturers apply for, earn, and keep the Energy Star label on products." Among several changes put in place, the online, automated self-certification system that allowed the fake companies to get bogus products approved was temporarily shut down while staff was trained to review all applications submitted.

The program also implemented a requirement for all new ES products to get independent third-party verification through accredited laboratories by the year's end. In addition to "off the shelf" spot checks and third-party testing, existing ES products will have to undergo verification testing to ensure continued compliance.

To read the full report, search for Energy Star at www.gao.gov.

Bogus products like this "air purifier" (a feather duster and fly strips attached to a space heater) were accepted as Energy Star-certified, sometimes without question.

Courtesy www.gao.gov



Courtesy www.canadiansolar.com

Zep Frame Detail

Canadian Solar's New Modules

In March, Canadian Solar (www.canadiansolar.com) released its NewEdge solar modules, the first modules to be compatible with the Zep Solar roof-mounting system. A groove in the module frame allows the Zep system's "Interlock" to connect and ground adjacent modules, negating mounting rails or individual module-grounding devices. Modules are secured to the roof and leveled with the Zep leveling foot.

Two Canadian NewEdge module lines are available: the all-black 72, 5-inch cell series (CS5A-MX), which includes 180-, 185-, 190-, 195-, and 200-watt models, and the 60, 6-inch cell series (CS6P-PX), which includes 220-, 230-, 240-, and 250-watt versions. All NewEdge modules can be mounted to standard racking systems as well. Modules carry a six-year materials warranty and a 25-year power warranty.

Zep Solar PV Mounting/ Grounding Hardware UL listed

Courtesy www.zepsolar.com

In May 2010, Zep Solar (www.zepsolar.com) received UL 1703 and UL 467 listings for electrical grounding by ETL. The UL 1703 listing certifies that the Zep interlock mounting system automatically grounds each module as it is mechanically connected. The UL 467 listing certifies that the Ground Zep, which connects the equipment grounding conductor to the array, meets the criteria required for a grounding and bonding device.

Courtesy www.sma-america.com

SMA 8,000 Watt Windy Boy Inverter

SMA America (www.sma-america.com) added to its line the 8 kW Windy Boy 8000US batteryless grid-tied wind inverter. Windy Boy inverters are compatible with several wind generators, including those from Proven Energy, Southwest Wind Power, Abundant Renewable Energy, and Evance. All SMA wind inverters now carry a 10-year warranty.

SMA-America Assembly

As of May 2010, SMA America products made at the company's new Denver, Colorado, facility comply with the "buy American" clause that's required for projects receiving funding via the American Reconstruction and Reinvestment Act of 2009. Models assembled in Denver include Sunny Boy batteryless inverters (3 to 7 kW). As soon as September, the Sunny Island line of battery-based inverters will be assembled in the United States as well.

Tyco SOLKLAMP Grounding Bolt

Tyco Electronics (www.tycoelectronics.com) has introduced its UL-listed SOLKLAMP grounding bolt. The stainless steel, threaded split-bolt uses the PV module's designated grounding hole to secure a solid bare copper wire (#6 to #12 AWG) for module-frame grounding. This grounding method is especially helpful in jurisdictions that do not allow the Wiley Electrical Equipment Bonding (WEEB) method. It also provides another option to the commonly used tin-plated copper lay-in lug, which uses a terminal screw to secure the ground wire and requires PV module surface preparation. SOLKLAMP's sharp edge cuts into the module's surface when the mounting nut is tightened.

—Justine Sanchez

Courtesy www.tycoelectronics.com

The Louisiana Green Corps

Building Green-Collar Careers

After high school, Christopher Williams, 22, wanted to do something to help people. He planned to save for college and pursue a career in health care, but after reading about green building and renewable energy, he realized there was more than one way for him to care for the people in his community.

Williams decided to learn a trade and do his part to help rebuild the region "the right, healthier way," he says. In April 2009, he began his training with the Louisiana Green Corps—a workforce development program jointly managed by the Alliance for Affordable Energy (AAE), the ARC of Greater New Orleans, and the Old City Building Center.

Based in New Orleans and funded in part through a grant from the U.S. Labor Department, the seven-month program prepares young adults for entry-level employment in the state's emerging "green-collar" economy. Certified contractors and practitioners provide classroom and on-the-job training in basic carpentry, building weatherization, energy-efficient technologies, and solar hot water installation.

The program reaches out to low-income young adults who lack work history, have a criminal record, or possess intellectual or physical disabilities. "So long as they have the desire to learn and willingness to work hard, then the Corps is happy to have them," says Forest Bradley-Wright, AAE's sustainable rebuild director.

Inspiration for the program came in the aftermath of Hurricanes Katrina and Rita in 2005. The program capitalizes on the rising demand for green building services and provides a pathway out of poverty for young adults who were struggling to find employment in the storm-weakened economy.

"In New Orleans, we have really failed in preparing our young people to find viable employment after high school, and as a result, too many of them get involved with illegal activities," Bradley-Wright says.

"That's where the Green Corps comes in. We're helping young people see their potential and get on the first rung of the career ladder. And, even more importantly, we're empowering them with the satisfaction that comes from making a positive difference in the community," he adds.

Twenty percent of the participants' time is spent on individual education pursuits, such as basic literacy, general education development (GED), or college preparation. Participants also receive technical certifications through the Occupational Safety and Health Administration, the National Center for Construction Education and Research, and the Building Performance Institute.

Hands-on training and service projects constitute the majority of their work. Projects range from sealing air gaps to installing radiant barriers and insulation. Over four terms, the Green Corps has weatherized and rehabilitated 93 low-income homes in the New Orleans area—many of which are located in the Lower Ninth Ward, one of the areas still recovering from Katrina and Rita. Many projects are provided to low-income, elderly, or disabled residents at no cost, while others are offered at market rate prices. Crews also installed nine solar hot water systems and assisted with several Habitat for Humanity building projects throughout the region.

In addition to a weekly paycheck, participants receive a financial AmeriCorps education award that can be used to pursue a variety of post-secondary coursework during and after the program.

"I must admit that I thought it was a big hoax, just another program to get kids off the street. But I'm a believer now," says Williams, who plans to use his education award for additional training in energy efficiency, with the ultimate goal of becoming a certified home energy rater.

So far, 177 people have graduated from the program—37% have found jobs in their field and 33% have used their

Green Corps participants learning home weatherizing techniques on the job.

Courtesy www.all4energy.org

AmeriCorps education awards to finance higher education endeavors. A number of graduates now work with the Total Community Action Weatherization Assistance Program, a federally funded program that helps low-income families in New Orleans make energy-efficient upgrades to their homes.

After completing the program, Williams landed a job with Brothers Way Construction in New Orleans. He credits the Corps with showing him that one person can make a difference.

"People are always talking about bringing New Orleans back," Williams added. "I say why not bring it back in a safer, greener way."

—Kelly Davidson

Similar "green corps" programs are available in several states and cities across the country. Search the Web for a program near you.

The Alliance for Affordable Energy

The Louisiana Green Corps is one of the Alliance for Affordable Energy (AAE)'s most recent collaborations. The nonprofit group has been helping shape Louisiana's energy future since 1985, working at the state and local levels to advocate for policies that promote energy efficiency, sustainable building, and renewable energy.

The oil spill off the coast in the Gulf of Mexico has reinforced the importance of the group's work, according to Forest Bradley-Wright, AAE's sustainable rebuild director.

"What happened with the oil spill is a huge wake-up call for the people of Louisiana," Bradley-Wright says. "It has people thinking about where their energy comes from, how safe it is, and whether it is good for our future. The national spotlight is on us once again, and it's our chance to be proactive and make smart choices that move us toward clean, renewable technologies."

For its part, the AAE monitors the proceedings of the Louisiana Public Services Commission and intervenes, as necessary, with recommendations to ensure that electricity ratepayers' interests are represented. Most recently, the group has focused its regulatory efforts on the creation of a Renewable Energy Standard that would require Louisiana utilities to purchase a percentage of their energy from renewable sources. The group has had an active voice in the discussion, advocating for more stringent benchmarks. To learn more, visit www.all4energy.org.

Island Ingenuity


Courtesy Dave Cozine

In February 2010, the underwater power cable feeding Anderson Island, Washington, broke, leaving the residents without power. A stopgap solution—diesel generators the size of trucking containers—were used to supply electricity to the island's 1,100 residents. But high fuel costs and the pollution from the generators forced residents to examine other power options.

Chuck and Kelly Hinds were islanders who lived without grid electricity for more than two months, and decided to investigate solar as a more reliable source of electricity. With views of Nisqually Delta, the Olympic Mountains, and Mt. Rainier, the Hinds' house sits on a high bank on the southern tip of the island. The house's roof had decent solar exposure, but its octagonal-shaped, standing-seam metal roof wouldn't easily accommodate a PV array. An awning or front deck cover for the PV array was another option, but the array size would be limited to the deck area and an awning would have impaired the view from inside the home. The chosen option—a new PV-covered carport—added a bonus: a 120-volt outlet for charging an electric car.

For grid-tied solar-electric installations, Washington State production incentives have a standard base rate of 15 cents per kWh generated from the PV system. The incentive goes up to 36 cents if Washington-made modules are used. If the inverter is also manufactured in the state, then an additional 18 cents is paid. (The program is in effect until June 30, 2020, with the maximum incentive capped at $5,000 per year.)

Using Silicon Energy's Cascade Series PV modules and OutBack Power Systems' SmartRE3000 inverter—both made in Washington—entitled the Hinds to the full 54 cents per kWh. With payouts like these, the decision to cover 100% of their electricity needs was an easy one, since the system's payback is 10 to 12 years.

The Cascade Series PV module and installation system has some unique features. The polycrystalline modules use a proprietary frame/racking that conceals and protects wires. Each module is laminated—with glass front and back—and smooth frameless upper and lower edges easily shed water, snow, and ice. The "cascading" feature leaves a gap at the bottom of each row of modules to increase airflow, helping keep cell temperatures down for better module performance.

Five strings of four modules cover the 16- by 20-foot carport. The strings terminate in an OutBack combiner box. Underground wiring connects to the inverter. Four 105 Ah Deka AGM batteries complete the installation, providing electricity when the grid goes down: 3 kWh of backup energy at a 60% depth of discharge. During a utility power outage, the Hinds want to run their computer, refrigerator, gas fireplace insert fan, and some compact fluorescent lighting. According to a Solar Pathfinder analysis, during the winter the array will receive an average of only 2 daily sun-hours, providing backup electricity for one to two days.

If more energy is needed, the Hinds can use their diesel generator. But they're counting on their solar-electric system to fully pay their annual electrical bill, hedge expected utility rate increases, and to pull them through future island power outages.

—Dave Cozine

Overview

Project name: Hinds residence

System type: Grid-tied PV with battery backup

Installer: Brothers Electric & Solar

Date commissioned: April 2010

Location: Anderson Island, Washington

Latitude: 47°N

Average daily peak sun-hours: 3.6 (2.0 in winter)

System capacity: 3.4 kW STC

Average annual production: 3,000 AC kWh

Average annual utility bill offset: 100%

Equipment Specifications

PV modules: 20 Silicon Energy SiE170

Tilt angle: 25°

Array installation: Carport

Roofing material: PV modules

Array azimuth: South

Module rating: 170 W STC

Inverter: OutBack SmartRE3000, 3,000 VA

Batteries: 4 DEKA 8A31DT AGM, 12 V, 105 Ah

System Spot-Check

Is your grid-tied PV system generating the amount of energy it should?

One of the beauties of a solar-electric system is that there are no moving parts. The PV modules silently sit in the sun, doing their job of producing electricity. But, do you know how well they are doing their job?

With access to grid electricity (unless there is a utility outage), owners of grid-tied PV systems often are not as engaged in monitoring their systems compared to their off-grid counterparts, who critically rely on their systems for every bit of their energy. For many, the only indication of a problem comes in the form of a higher electric bill—a month later—and even that might go unnoticed for some time. It is important to spot-check the system regularly to make sure it is performing as expected.

Checking Watts

Choose a clear, sunny day around noon to check system power output (watts). Find this value on your inverter's faceplate meter or remote monitor, and compare it to your array size, adjusted with a derate value to account for system inefficiencies. System efficiency ranges from 70 to 80%, accounting for power losses from module heating, dust, inverter inefficiency, wiring voltage drop, and module production tolerance and mismatch.

For example, if you have a PV array rated at 3,000 W, you can expect the output to be 70 to 80% of that value (2,100 to 2,400 W) on a sunny day. If you read a value that is significantly lower than expected, and there is no obvious reason (like shade, a day without full sun, or extremely dirty modules), a call to your installer is a good idea. A common culprit for lower-than-expected performance is a blown fuse in a combiner box (or in the inverter, if it has integrated series string fusing).

Courtesy www.fronius.com

Checking Watt-Hours

While checking watts is a good spot-check on power, also periodically check the kWh (energy) production total. Using this value requires that you know when your system was installed, its shading factor, and array orientation and tilt.

You can use NREL's PVWatts program (http://rredc.nrel.gov/solar/calculators/PVWATTS/version1/) to find the expected system output (monthly and annual) and then compare them to the actual kWh reading. (See *Sizing Batteryless Grid-Tied Arrays* in this issue for more information.)

For example, let's say a 3 kW system was installed on October 1, 2010, on a home in Billings, Montana. Eighteen months later, the inverter or production meter shows total energy produced is 5,050 kWh. You can plug in system variables into PVWatts to compare the predicted value with the kWh total. In this example, assume a 0.90 shade factor and a south-facing array set at a tilt angle equal to latitude. PVWatts reports expected annual kWh production at 3,597 kWh. But this system has been running for 18 months, so we need to add in the monthly totals from the additional six months (October–March adds 1,541 kWh). Using this, we get 5,138 kWh as a predicted value—within 2% of the actual value. Note that while inverter faceplate meters (and production meters) generally only keep a running kWh total, and not monthly totals, users can track this by recording their kWh total at the beginning of each month. Then, by subtracting the preceding month's total kWh from the current month's kWh, they can use these values to compare to the PVWatts monthly predicted values. However, keep in mind that variable weather patterns can impact energy production. For example, if a particular month is much cloudier than usual, the system's energy production will likely be lower than the PVWatts predicted value.

If there is a wide discrepancy (i.e, more than 5% and lower than expected) that cannot be explained by unusual weather, examine the solar window for increased shading (from growing trees, etc.), and call your installer to look for problems such as poor inverter maximum power-point tracking or failed module bypass diodes.

—Justine Sanchez

Note: painting flames on your module may affect performance

Solar Start

After subscribing to *Home Power* for years and looking at solar electric a few times, we finally had the financial ability to start going more green. We added a solar hot water system. Our house has gas boiler radiator heat, so a third loop was added in the tank as the backup. It's been great fun to watch the temperature climb on the collectors, and 130°F to 150°F glycol going into the tank loop. We won't know what we may be saving in natural gas for some time, but we are happy to be doing "something."

Larry & LaDonna Carlson • Seattle, Washington

Courtesy Larry & Donna Carlson

What Shade of Green?

I have already become tired of the word "green" and how it is used to describe virtually every product on the market. It seemingly now has little to do with its original intent—color! Green was always one of my favorite colors. I'm a 26-year New York Jets season ticket holder, so kelly green is special to me. I am the son of the former Rita C. McDarby, so emerald green is in my DNA. I like to make money, so "$ green" is always in my consciousness.

The devaluing of the word "green" by attaching it to everything from furniture polish to soldering flux has gotten completely out of control, so I am starting a movement to return "green" to its former glory by offering some alternatives to the now over-exposed and clichéd use of the word.

In my work with solar thermal systems, I have become increasingly concerned about products and systems that are being bunched together under the "green" moniker, but when one looks a bit closer, the *shade* of green may be in question.

Here's my point: I am fortunate to have many friends in the HVAC industry and many of them are getting involved, in one way or another, with solar products. A company that is very close to my heart is announcing a solar thermal product offering this year; they sent me some information on their intended offering and asked my opinion. The product is a fine unit manufactured in Israel, where solar hot water has a huge market for reasons that may or may not be obvious. No one would sell the Israelis oil, so necessity literally became the "mother of invention," and solar hot water systems are found on virtually every home and building in the region.

My concern with such a product from Israel coming to market here in the states is strictly a logistical one. How green can a product be when it has to travel 6,900 miles via container ship to get here? Ships measure their fuel usage in pounds of fuel per horsepower per hour. Good fuel economy on a container ship is 0.25 pounds per horsepower per hour. A typical container ship has engines totaling 100,000 hp. This works out to 25,000 pounds of marine diesel fuel per hour. Marine diesel weighs about 7 pounds per gallon, which translates to about 3,600 gallons burned per hour. I understand that a typical container ship cruises at about 25 knots (about 30 mph); so to go 6,900 miles, it will burn 828,000 gallons of fuel!

As a result, I don't think I can call a solar thermal product from Israel "green." According to Wikipedia, there are at least 49 shades of green, so maybe the product should be called "gray asparagus," since neither the color nor the product's initial carbon footprint seem very green at all.

Hey, I don't want to come off sounding holier than thou here, so I must fess up to my own color faux pas. I have been involved with a solar thermal company for several years that imports products from Germany. There are 4,200 miles between the United States and the origin of this product, so maybe I have to call this product "olive green," or maybe I should save that shade for an Italian product.

My concern for solar thermal products that travel thousands of miles to get here is reminiscent of the bamboo flooring that was all the craze here in the states five or six years ago. The general consensus at the time was "what could be greener than a floor made of an organic material such as bamboo?" Well, someone (not me), started to calculate the devastation caused by less than environmentally friendly harvesting techniques and the fuel used to transport

the product from Asia to the U.S. market, and suddenly the shade of green changed for bamboo flooring.

I am making a personal commitment to start seeing green in the totality of a product, not just in its perceived use and appearance. The good news is that there are U.S. manufacturers of solar thermal collectors and controls. My bottom line is that maybe we need to start seeing green as red, white, and blue.

Gerry Wagner •
www.walesdarbylearningcenter.com

Hot Water Perspective

I read John Vastyan's article "SHW Retrofit" in *HP135.* As stated in the article, mixing an evacuated-tube system with a flat-plate system was part of an experiment. My concern with this hybrid system is how to control it—I do not see it as a well-thought-out experiment.

Assume the collector sensor is on the evacuated-tube collector. In the winter, the evacuated-tube system will experience less thermal loss and, as a result, will (at times) be at a higher temperature. If the pump comes on, the fluid will pass through the flat-plate collectors, which may actually cool the fluid before it reaches the evacuated-tube collector. Because the flat plates have more surface area than the evacuated-tube collector, the net result could be cooling the storage tank.

Similarly, evacuated-tube collectors are slower in responding to solar input (because they have a heat pipe that needs to boil before heat transfer starts). Thus, the flat-plate collectors may be at operating temperature before the evacuated-tube collector is warm enough to start the pump. This could result in the hybrid system providing less solar input than a conventional flat panel or evacuated tube system.

Steve Dyck, Guelph Solar Hot Water •
Guelph, Ontario, Canada

Common Ground

I've been reading your magazine intermittently for the past couple years to find ideas and information on how to be self-reliant on my moderately large (400-acre) farm that is remote enough that the reliability of the utility grid is questionable at best. I anticipate installing a number of technologies during the coming year, including solar thermal for both hot water and hydronic heating, photovoltaic modules on my house, a water-pumping windmill, and a hydro-electric system that will generate three-phase power for shop equipment and other machinery. I'm also considering raising biodiesel crops to process on site to fuel tractors, farm trucks, and diesel-powered personal vehicles. It might surprise you to learn that in spite of my willingness to invest in alternative energy technologies, I'm a heretic who rejects global warming theology, have always been and remain supportive of nuclear power, favor drilling for oil offshore and in ANWR, and view coal as a viable option until new technologies can replace it at reasonable cost.

Although it is hardly unique to your magazine, the photograph of the Ackerman-Liest family with their three children on the cover of *HP136* illustrates why I believe that the readers of your magazine might find that they have much in common with Neanderthals such as myself. This family, living on their rural homestead where they can use the space available to them efficiently to meet their energy and food needs, represents what I hope is the future.

This is a contradiction to the more politically correct paradigm of Draconian land-use planning regulations, which are intended to drive people off the land and herd them into concentration camps called cities, where they live in high-rise apartment buildings. Rather than being able to use the sun and wind to meet their own energy

needs, they remain utterly dependant on a utility. The only token gesture towards energy self-sufficiency might be a "district energy system," which is nothing more than a natural-gas-fueled generator in the basement that provides a modest amount of electricity and thermal energy for water and space heating. The intense crowding combined with social pressures and perhaps legal restrictions may ensure that these city dwellers will have few, if any, children.

The need for brevity would make it inadvisable for me to try to explain why I disagree with the editors and most of the readers of *Home Power*, even if it wouldn't provoke needless argument. However, I believe that we share an optimistic view of the future in which humanity adapts and thrives rather than simply fades away.

James W Crawford • Yamhill, Oregon

Errata

In the "2010 Wind Generator Buyer's Guide" (*HP137*), we neglected to include the Ventera wind turbine. The data is shown in the table.

In the same article, there was an error in Gaia-Wind's pricing. The actual price is $83,000, which includes the tower and foundation kit, but not installation.

Ventera Turbine Specifications

Manufacturer/importer	Ventera Energy
Web site	www.venteraenergy.com
Model	VT10-240
Swept area (sq. ft.)	380
Rotor diameter (ft.)	22
Tower- top weight (lbs.)	500
Predicted AEO (kWh)	
8 mph	3,588
9 mph	5,262
10 mph	7,290
11 mph	9,661
12 mph	12,341
13 mph	15,266
14 mph	18,347
Rpm	270
Generator type	PM
Governing system	Blade pitch
Governing wind speed (mph)	29
Shutdown mechanism	Dynamic brake
Batteryless grid-tied version	Yes
Battery voltages	—
Controls included	Yes
Tower or installation included in cost	No
Cost: batteryless version	$21,200
Cost: battery charge version	—
Warranty (years)	5


Ventera VT10

write to:

mailbox@homepower.com

or Mailbox, c/o Home Power
PO Box 520, Ashland, OR 97520

Published letters are edited for content and length. Due to mail volume, we regret that unpublished letters may not receive a reply.

Courtesy Dan Fink

Steam Electricity

I live in an off-grid cottage and my biggest energy expense is for propane, which I use for space heating in winter. Because my farm has more firewood than I can possibly use, I'm planning to install a wood-fired, water-heating stove to eliminate the need for propane. I would like to find a way to convert wood to electrical energy as a backup, so I don't need to rent a generator and can run electricity to other dwellings and buildings on the farm.

I know this technology was around long ago, because steam locomotives used it to generate electricity for their running lights. Only 100 to 150 psi of steam was needed. A small boiler/turbo generator could be installed for backup or full-time power as needed, with no dependency on outside energy sources.

Are there any companies that make small boiler turbo generators (5–20 kW) that could be run on wood?

Clyde Koral • via e-mail

You'll likely be out of luck trying to buy a commercial, home-scale steam turbine generator that burns wood, for two very good reasons—safety and practicality.

Water expands to 1,700 times its original volume when heated to steam, and each gallon of water in a boiler carries the potential energy of a stick of dynamite! Boilers for steam turbines and steam engines must be monitored constantly, especially when burning fuels like wood where the energy density varies from one chunk to the next. Even a 10-minute trip to the fridge for a soda and sandwich is too long to leave a wood-fired steam system unattended.

We have a wood-burning steam engine here at our off-grid shop, spinning a 2 kW alternator, but it's there for fun, not to depend on for backup electricity. Someone has to monitor, stoke, and water the boiler all day long, thus getting little work done in the shop, making steam backup power impractical for us. Steam power is fascinating, though, and there are many science-fair-sized steam turbine models on Internet video sites, or you could join a steam-engine enthusiasts club for help in restoring an antique or building your own.

There are other options besides steam for making electricity from wood, but all are complicated and expensive do-it-yourself projects at the 5 to 20 kW scale you want:

- Stirling cycle engine: These heat-powered machines are quite safe, but very pricey. Plans for machining and building your own are available, but few actual products larger than toy model fans for your wood heater exist. Plus, they have a reputation for early failure.

- Thermoelectric cells: Also common in wood heater fans, these use the Peltier-Seebeck effect to make DC power directly from heat. Modules of 25 to 100 watts are very expensive, and past products have suffered reliability problems from overheating.

- Wood gasification: This technology uses heat and chemical reactions to break down wood into flammable gases for burning in a standard internal combustion engine. Tens of thousands of vehicles were retrofitted with gasifiers in Europe and Asia during 1940s wartime gasoline shortages. You can buy a parts kit today to build your own, and plans abound. However, wood gas is not a "hit the switch and forget it" sort of fuel, and deadly carbon monoxide is one of the gases it produces and burns. You can't just throw logs into your gasifier; charcoal, sawdust, or very small chunks of wood are required. Gasification is a very advanced do-it-yourself project, but is probably your best bet if you choose to continue your quest.

Making electricity with firewood is a difficult way to go, and requires lots of time, money, advanced skills, and imperturbable enthusiasm. If I had a huge surplus of wood as you describe, I'd harvest sustainably, sell the extra wood, and invest the proceeds in greater energy efficiency for my home and more solar-electric modules for my roof.

Dan Fink • www.otherpower.com

How Many Blades?

There is not all that much wind where I live, so I'm looking for a machine with good low-wind performance. I noticed a new wind generator on the market that has five blades instead of three. Can I expect that turbine to be relatively more efficient at lower wind speeds because it has more blades?

Jheroen Dorenbosch • Dallas, Texas

The main factors controlling the power output of wind turbines are the wind speed and the size of the turbine, though efficiency also plays its part. The blades of a particular turbine will be designed to work well with its alternator and its load. In any particular strength of wind, the blades' most productive rotational speed needs to match the rpm at which the alternator produces the power that is available in that wind speed.

A turbine designer will choose the number and shape of the blades based on the machine's working rpm. A high-rpm turbine needs fewer, more slender blades, whereas a slower machine needs more torque and more blades. However, the blade efficiency is not likely to be significantly different provided that the designer has done a good job. In most cases, designers choose three blades because that is the fewest that run smoothly. Alternators work better at higher rpm, so overall three is the best number of blades. Also, fewer blades may reduce the machine's overall cost.

Some turbines fail to start up in very low wind speeds. The ability to start depends on the number of blades, and on the friction and magnetic drag in the alternator. A machine with more blades has a better chance of starting sooner, but there is very little energy to be had in such low winds, so there is no real advantage.

It is theoretically possible to achieve a slightly higher blade efficiency with five blades compared to three blades if all else is equal. But this is more than offset by the alternator's superior performance at the higher speed achieved by a three-bladed rotor. Bottom line: There is no real benefit to having more than three blades.

Most important is siting a wind turbine on a tall enough tower in a windy enough place. No special design feature will change this basic fact.

Hugh Piggott • www.scoraigwind.com


Courtesy www.scoraigwind.com


Courtesy www.scoraigwind.com


Courtesy wwww.kestrelwind.co.za

Which Windows?

I'm looking for windows that provide maximum solar gain for a passive solar structure I'm building in eastern Oregon.

I found one Canadian company that manufactures a triple-paned fiberglass-framed window with a solar heat gain coefficient (SHGC) of 0.59 and a U-factor of 0.29. Ideally, I would like a higher SHGC without keeping the U-factor low.

Surely a better window concept has been developed. What I've found from window manufacturers is a complete lack of concern for the passive solar market. Are we that much of a minority?

Ron Miller • via e-mail

You're not going to find a triple-glazed window with a higher SHGC. In fact, assuming you are talking about the window's whole-window U-factor as reported on the NFRC label rather than the glazing U-factor, it's possible that the window manufacturer you spoke with is exaggerating. For an operable casement window, clear triple glazing is more likely to provide a whole-window SHGC of 0.47 and a whole-window U-factor of 0.29.

Adding one or more low-e coatings to your triple glazing will improve your window's U-factor. (U-factor is the inverse of R-value; the lower the U-factor, the better, since a low value indicates the ability of the material to resist heat flow.) If you want a low U-factor, you can buy triple-glazed casement windows with a U-factor as low as 0.17. That's good. The downside to a low-U-factor window is a lower SHGC—in this case, only 0.25.

Choosing the best south-facing glazing is a balancing act. If your region of Oregon is cloudy during the winter, a high SHGC window may be less important than you think. After all, since that high-SHGC window will also have a higher U-factor, it will be leaking more heat at night and on cloudy days than a low U-factor window. Where I live in Vermont, I like to specify south-facing triple-glazed windows with compromise glazing—one hard-coat low-e coating—which results in a U-factor of 0.21 and a SHGC of 0.33.

You're right that most U.S. window manufacturers have abandoned the high-solar-gain glazing market. That's why passive solar builders usually buy windows from Canadian manufacturers.

For more information, check out my articles on high-solar-gain windows at www.greenbuildingadvisor.com/blogs/dept/musings.

Martin Holladay, senior editor • GreenBuildingAdvisor

Courtesy: www.quantumbuilder.com

I ran into the same issue when I was specifying high SHGC/low U-factor south-facing windows for my passive solar home—also in Oregon. Two local dealers I spoke with said what I wanted wasn't possible. They were telling the truth, but *only* when talking about their companies' particular product offerings.

So I turned to the Efficient Windows Collaborative (www.efficientwindows.org) to find some windows that fit my specifications. Their window selection tool allows you to search by glass and frame type, specify Energy Star-rated units, and search for windows for new or existing construction. Then, it reports on the products available and what company offers them.

Claire Anderson • *Home Power*

Off-Grid Machine Shop

I have been happily living off-grid for the past two years and am wondering if it is possible to run an off-grid machine shop. Currently, I am using a 15 kW genset to run my lathe, milling machine, welders, etc. Can any current inverter configuration run such high-power demands as these?

Rick Amendola • Cochrane, Ontario, Canada

You have provided two key pieces of information: Your 15 kW generator meets your shop needs now, and you're happy living off-grid. Obtaining the inverter capacity is one of the easier parts of the picture—options include: An OutBack "quad-stack" (four VFX3648 inverters, wired 120/240 in series/parallel, which allows 14.4 kW, continuous) would handle anything that your generator now powers. Schneider's (formerly Xantrex) XW series allows two or three 4.5 or 6 kW 120/240 V inverters to be stacked in parallel. SMA America's Sunny Island units can be combined to supply 10 or 20 kW at 120/240 V. Magnum Energy has recently upgraded their MS-PAE series to allow parallel stacking of up to four units, thus providing up to 17.6 kW.

Your shop likely doesn't need a full 15 kW of inverter capacity, since most motor loads have high starting surges, which inverters can handle better than your generator. If a 15 kW generator runs your shop, you're probably using split-phase 120/240 VAC power, but three-phase 120/208 VAC power can also be produced with some modern inverters.

Inverter kW capacity to run the shop equipment is only part of the picture. The other part is kilowatt-hour capacity—how much energy does your shop consume in a typical day, and how can that be met with renewable resources? Your inverters are powered by batteries, and the battery bank must be recharged by a combination of sun, wind, hydro, or your generator.

To determine the amount of renewable energy you will need, my first suggestion is to add a standard electric meter and meter base between your generator and your shop, so that you can determine how many kilowatt-hours are used from day to day. This will soon give you an idea of your daily energy budget, so you can size your renewable resources and batteries to meet the majority of these needs. Make sure that you also consider ways to reduce your consumption, using daylighting, efficient artificial lighting, and modern high-efficiency motors, since many efficiency upgrades quickly pay for themselves in reduced system costs.

You will want to integrate your existing generator into your RE system. Rather than run your shop equipment, its role will be to make up any deficit between RE production and consumption. Given the Ontario climate, if you use PV as your main charging source,

you will likely depend on your generator as your backup source during cloudy winter weather—thus you may also consider a wind turbine if you have a good wind site. The primary role of your generator will be to periodically charge your batteries through your inverter(s), rather than run the tools directly. This way, the generator run time is greatly reduced, and the generator is always well-loaded and running in balance, increasing its efficiency.

Back in 1994, I knew someone who successfully ran an off-grid woodworking shop on a pair of early Trace SW-series inverters. He learned that while the inverters needed to provide substantial "kick" (watts) to start and run shop equipment, actual daily consumption (watt-hours) was fairly modest, as the larger tools typically ran for short durations and were then shut off. While I understand that machine tools typically consume more energy and run longer than woodworking tools, you may find this to be the case as well.

Finally, assuming your home and shop are close to each other, I would encourage you to use one large system to run both home and shop. Either expand the existing home system to also run the shop, integrate the home equipment into the larger shop system, or sell the home equipment and run the home off the new large shop system. A single system is more cost-effective than two smaller systems, and you will quickly learn to pay attention to your system's care and feeding, making it easy to relax with sufficient energy at home after the day's work is done.

Allan Sindelar • Positive Energy

The Tube vs. Flat-Plate

Even after the *HP132* article on evacuated-tube and flat-plate solar thermal collectors, I still have one nagging question. Your article and myriad other publications nicely explain why flat plates have lower efficiencies at lower ambient temperatures—it's a matter of insulation and heat loss. Why do evacuated tubes have lower efficiencies at high ambient temperatures?

This is especially perplexing, since many flat-plate proponents say that evacuated tubes are not as efficient as flat plates in summertime temperatures, but that EV tubes are prone to summertime overheating. Well, which is it?! Either they produce fewer Btu in the summer or more. It sounds like the summertime inefficiencies of evacuated tubes are more related to the method of extracting the heat from the collector and not the collector itself. I know this may just be a problem of semantics, but could you please help explain what is happening at the other end of the efficiency curve?

Benjamin Feusi • Kelsey, CA

First, a little background on collector efficiency. Collector high-end "efficiencies" are published under a condition where the collector inlet temperature is equal to ambient outside temperature (Ti = Ta). Under these conditions, insulation is just about worthless, since there is little or no heat loss. As the collector inlet gets warmer in relation to the ambient temperature, insulation becomes more important. Under conditions where the inlet temperature is more than 150°F above the ambient temperature, the insulation is of supreme importance, hence the superior performance of the highly insulative vacuum of evacuated tube collectors under these conditions.

Collector construction determines performance. The maximum theoretical efficiency of a flat plate or evacuated tube collector is about 80%. A single layer of

glass will absorb/reflect about 10% of the sunlight and the total absorber efficiency of any type collector will cost another 10%. Absorber efficiencies directly relate to how much energy the absorber can transfer into the collector-loop fluid. Absorber efficiency is determined by the absorber material, absorber coating, and, to a lesser extent, the size of tubing in the absorber.

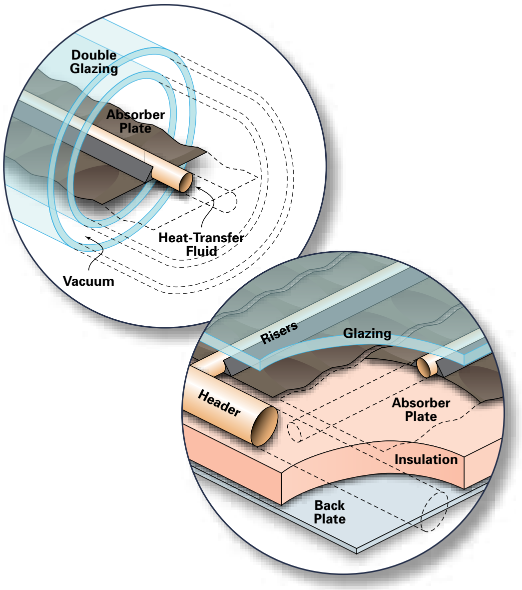
A well-made flat-plate collector has a single layer of glass and an efficient absorber. Manufacturers take care in ensuring the tubes in an absorber are well bonded to the plate for maximum heat transfer. Many manufacturers have collectors published in the SRCC catalog with Ti = Ta efficiencies in the mid- to upper 70% level—getting very close to the theoretical maximum.

A well-made evacuated-tube collector is more complex. Some of the collectors have a single layer of glass and an absorber plate. Again, you'll find a maximum efficiency of 80%, since the vacuum doesn't help much, if at all, when Ti = Ta. A heat pipe is bonded to the absorber inside the tube to transfer the heat from the absorber to the collector-loop fluid. A different fluid with a low boiling point thermosyphons through a vapor/condensation cycle inside the heat pipe. The top end of the heat pipe plugs into a press-fit heat exchanger in the manifold at the top of the collector. A heat exchanger made with a mechanical 5-ton press can be 90% efficient. It would be difficult for a heat exchanger that is slip-fitted at the time of installation to be that efficient.

Many evacuated tubes have two layers of glass with the resultant loss of solar energy. Some tubes have the absorber coating on the outside of the inner glass and this lowers solar energy transmittance losses. But it also makes the glass the absorber, which is questionable for efficiency since glass is an insulator and heat conductors like copper make better absorbers.

Collectors made like this have two absorbers—the glass one with the coating and another metal absorber inside the glass, connected to the heat pipe tube that is then connected to the collector manifold tube. The inside absorber is held against the glass with spring tension from the curved metal. This type of collector will not transfer heat as efficiently as a simple flat-plate design made from copper.

Manufacturing processes can influence collector efficiencies. Some heat pipes are more efficient than others; some heat pipes are bonded to the absorber better than others, etc. One flat-plate manufacturer uses double-glazing with a trade-off: a drop in about 10% on the top-end efficiency and a gain in the insulation value of the second glazing and dead air space.



It boils down to this: Flat-plate collectors have a very simple, efficient path for heat collection and its transfer to the collector-loop fluid. Heat pipe evacuated-tube collectors have a more complex path and a resulting drop in the Ti = Ta efficiency. Insulation is supreme at higher temperature differences and simplicity is supreme at lower temperature differences.

Chuck Marken • Solar Thermal Editor

Recycling Batteries

I have about 17 old batteries to dispose of. They are made by Exide, and are in glass cases about 12 inches tall by 9 inches wide by 3 inches thick, with a positive and negative post at top. Are there any other uses for them or are they just destined for hazardous waste disposal?

Jack Ulrich • via e-mail

Batteries are too toxic (full of acid and lead) for the landfill, and are highly recyclable. In fact, lead-acid batteries have the highest rate of recycling of any other consumer product in the United States. Nearly everything in them is recyclable—including the lead, the acid, and the plastic or glass case.

Battery dealers will usually recycle old batteries for a nominal fee, or should at least be able to help you research the best place to take them. Any major automotive repair facility also should be capable of taking them—they recycle lots of car batteries.

If, by any chance, these are not lead-acid batteries, they are probably either nickel-iron or nickel-cadmium technologies. Neither of these latter types belongs in a landfill either. Both have caustic electrolyte, and cadmium is quite toxic. Both of these battery types are fairly desirable to some folks who like to refurbish them—consider listing them on www.craigslist.com or the local www.freecycle.org.

If you cannot find someone that wants to refurbish them, the batteries should be disposed of as hazardous waste. Please call Exide for a place to recycle them, or their recommendation.

Michael Welch • *Home Power*

write to:

asktheexperts@homepower.com

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SHARP

Habitat Goes Platinum

by John Vastyan & Traci Sooter

Energy-efficient design and careful material selection in this Habitat for Humanity home earned it the highest rating—Platinum—from the U.S. Green Building Council's LEED program.

Courtesy www.aillc.biz (3)

Many of us recall when Habitat for Humanity began to make headlines more than 30 years ago, winning President Jimmy Carter's support—he not only endorsed the organization but helped out with a hammer in hand. Since its inception in 1976, the nonprofit organization has built more than 250,000 houses, sheltering more than 1 million people in more than 3,000 communities worldwide.

Judging from its impressive number of new homeowners, Habitat has made huge strides in improving people's quality of life. Now, the organization is beginning to build homes that are more energy efficient to make a long-term difference for the occupants and the environment.

On a stretch of land just north of Springfield, Missouri, Habitat for Humanity's Legacy Trails housing development is offering a new paradigm of subdivision design. The focus has turned to establishing an environmentally friendlier neighborhood, with energy-efficient homes, native-plant landscaping, curbless streets to limit storm-water runoff, and bioretention swales that double as walking paths.

The newest home in the neighborhood—one designed and built primarily by Drury University architecture students—is a standout project that won recognition as the first-ever Habitat project attaining a LEED Platinum rating, a certification given for homes that achieve environmentally responsible and sustainable standards established by the U.S. Green Building Council.

Courtesy Traci Sooter

Although the home's design and construction was led by Drury University architecture students, students from all majors participated in building the Habitat home.

Courtesy Dan Frisch

A Learning Experience

The students, who designed the home as part of professor Traci Sooter's design/build course, worked on its design over two semesters and construction over $3^{1}/_{2}$ months, starting in the fall of 2007. Sooter says that Habitat "builds in a somewhat sustainable manner, simply by constructing efficient, small-footprint homes." But she was sure that her students could push the envelope further.

The student's goal for the two-story home was to make it as sustainable as possible. From decisions for the form of the building at the design level to material and equipment selection, all aspects of the home's construction were researched and considered by the team.

As design, material, and equipment decisions were made, the students rigorously researched the most sustainable—yet affordable—products and approaches. Cost is a big factor in a Habitat home, since affordability is tantamount to its mission of offering home-ownership to those who couldn't typically afford it. One of the first strategies to make this an affordable, LEED Platinum home was to use passive systems and design to help heat and cool the home.

The home takes its shape from the sun, wind, and site, as well as from the restrictions and requirements of a Habitat four-bedroom home; it also has a nod to the typical building style in the area. Primary to the design process was conducting a site analysis—Sooter's class researched prevailing winds and sun angles for the area and performed a site analysis at Legacy Trails.

Passive Strategies

The students designed the home to be longer on its east/west axis to increase southern exposure. This orientation maximizes solar heat gain in winter and also captures prevailing winds in the spring and fall, aiding in passive cooling.

Strategic placement of operable windows low on the south walls of the living, kitchen, and dining rooms allows air to enter from prevailing winds. High windows on the home's northern side ventilate the warmed air. This allows the homeowner to keep the space cool longer before resorting to mechanical ventilation or cooling methods.

To lessen heat gain in the summer while still capturing the solar heat in the winter, the roof extends past the edge of the southern wall to shade the wall and windows from the high summer sun. The roof angles back to the same wall

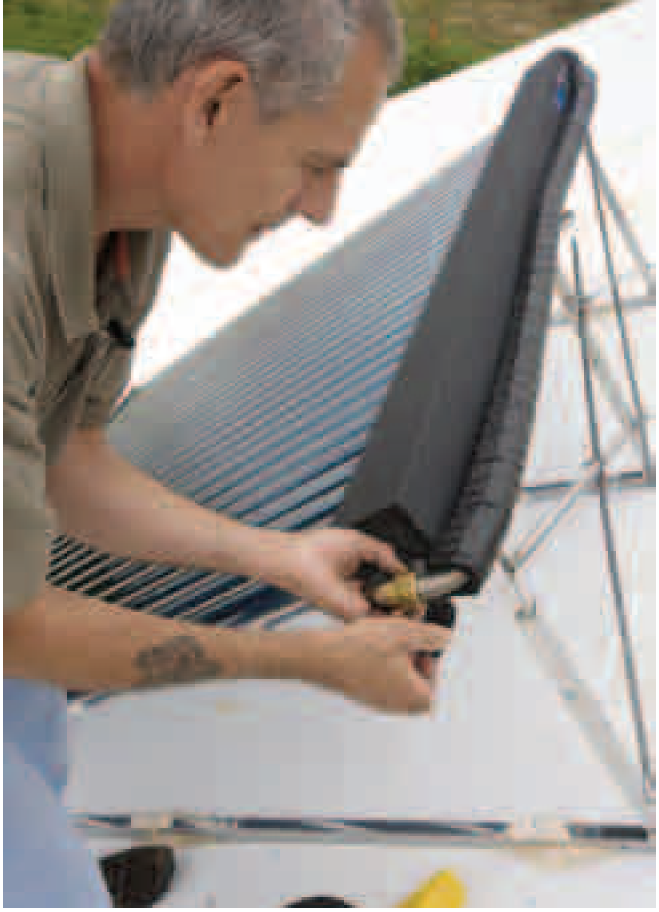
Choosing Materials

The students were demanding in their material selections, and recycled, recyclable, or reclaimed materials were selected when possible. As many products as possible were sourced within a 500-mile radius of the site in an effort to decrease the energy consumed during shipping.

The roof is 100% recyclable Thermoplastic Olefin (TPO) membrane. The self-sealing roof has a 30-year life span and was installed with water-based, low VOC glue. Its light color has an 87% reflectivity to reduce the home's cooling load.

The Patcraft Designweave carpet on the second floor is made of 100% recycled polymers. The first floor is concrete with a water-based stain for a durable, easy-to-maintain surface that also provides thermal mass for passive heat gain in winter.

The combination of Icynene spray-foam insulation in the walls and roof and caulking the wall studs limits air infiltration for improved energy efficiency. The wood siding is LP Smart Side, and has recycled content, a long life, and is volunteer-friendly—something important to Habitat. The students designed and built the kitchen cabinets from reclaimed wood. The stair rails are also constructed of a recycled steel.



Connecting lines to the 30-tube Apricus solar thermal array.

for aesthetic appeal. This approach allows the winter sun to hit the thermal mass of the concrete floor to collect and store radiant heat. The fifth-year Drury architecture students turned to their *Mechanical and Electrical Equipment for Buildings* text (see Access) to calculate solar angles and optimum square footage of glazing for the south façade of the home and its location. Heating systems manufacturer Watts Radiant then calculated loads to design the radiant heating system.

Beyond Passive

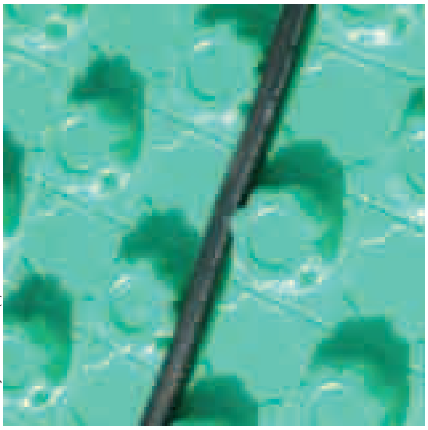
A 30-tube evacuated-tube solar hot water system provides about 70% of the energy needed for water heating. An electric boiler and an electric water heater provide backup for the floor heating and domestic water heating.

The rooftop-mounted collectors feed the heated propylene glycol antifreeze mix into an 80-gallon, twin-exchanger hot water tank. The glycol solution circulates in the superinsulated tank's lowest coil, exchanging heat with the large volume of contained domestic hot water (DHW). In turn, the DHW shares its heat with the uppermost coil, which supplies the home's two radiant heat zones.

During summer, the system reaches 160°F or higher. During winter, the solar array may heat the propylene glycol solution to about 110°F. Data from first few months of the home's occupation show that the solar heating system can

Hydronic tubing embedded in the first floor provides supplemental space heating when passive solar gain isn't enough.

An insulated matrix below the tubing thermally isolates the heating system from the ground and helps protect the tubing during the concrete pour.



Courtesy Dan Frisch (3)

Students install radiant heat tubing underneath the second-floor sheathing.

provide the majority of the domestic hot water—used for clothes washing, dishes, showers, and baths.

"Overflow" heat from the solar collector is expected to meet a small portion of the home's radiant heat needs during the winter months, with passive solar contributing the majority, and the backup boiler making up the difference. If there's abundant winter sunshine and the system produces all the DHW necessary, the system will assist with space heating.

Meeting LEED

To help meet USGBC LEED Platinum certification, the home also has dual-pane windows with low-e coatings, dual-flush toilets, and low-flow showerheads and faucets. All appliances and light fixtures are Energy Star-compliant.

Going through the LEED certification process, working directly with Guaranteed Watt Saver, the LEED for Homes provider, and working with Habitat for Humanity were great learning experiences for Sooter's students. They gained practical, hands-on experience in resolving their design at full scale, plus they learned how the LEED certification process applies directly to a home and influences design decisions.

Working with Habitat for Humanity gave students the experience of investing in their community. In the Habitat model, homeowners put in sweat equity as part of their down payment. This placed the students side-by-side with the homeowner, building friendships while building a home for a family.

Designing and building a sustainable home was born out of Drury's yearly convocation lecture series during the 2004-2005 theme year on sustainability. Members of the committee thought it would be great to create a sustainable project in which the entire campus could participate. And, in fact, they

(continued on page 50)

The hydronic system's manifold is assembled.

Tech Specs

Overview

System type: Antifreeze, evacuated-tube solar hot water

Location: Springfield, Missouri

Solar resource: 5 average daily peak sun-hours

Annual production: 8 million Btu

Percentage of DHW produced annually: 60% to 70%

Equipment

Collector: 30-tube, Apricus

Collector installation: Roof-mounted, oriented to true south, tilted at latitude (37°)

Heat transfer fluid: Rhomar HD propylene glycol

Circulation pump: Caleffi solar pump station model 255060, with integrated Wilo Star 16

Pump controller: Watts Solar

Storage

Tanks: Heat Transfer Products, SSU-80, 80 gal., dual-coil

Heat exchanger: Integrated in tank

Backup DHW: Electro Industries, 6 kW wall-hung boiler for the radiant heating system; 40-gal. electric tank for DHW; The Superstor tank preheats the DHW and supplies radiant from the upper coil.

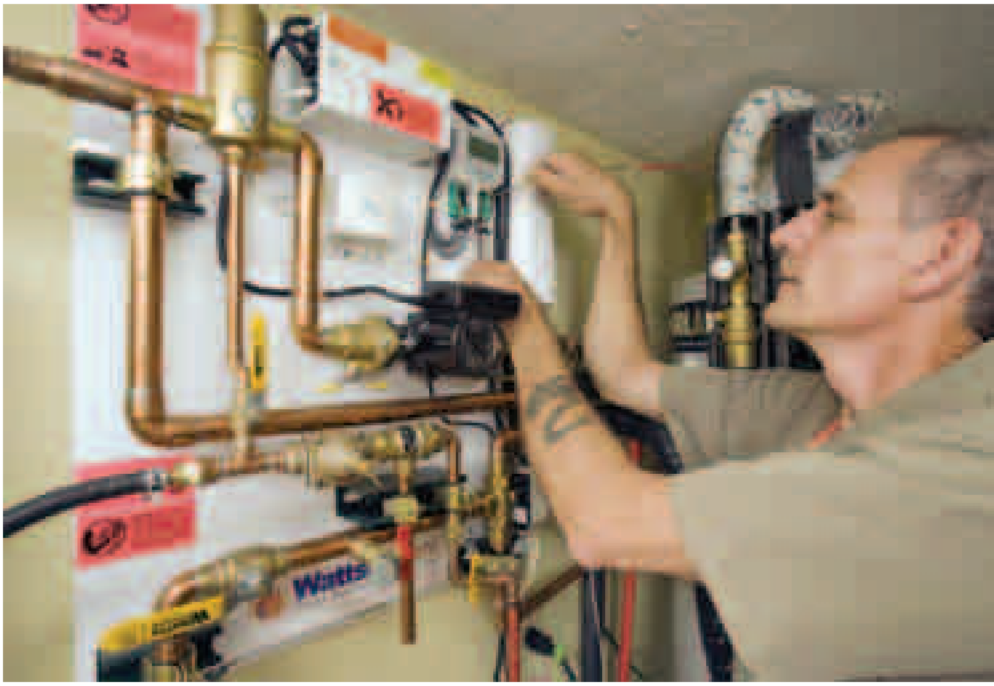
System Performance Metering

Thermometer: Watts Solar Controller with heat-metering function and data logging

Flow meter: Integrated with Caleffi solar pump station

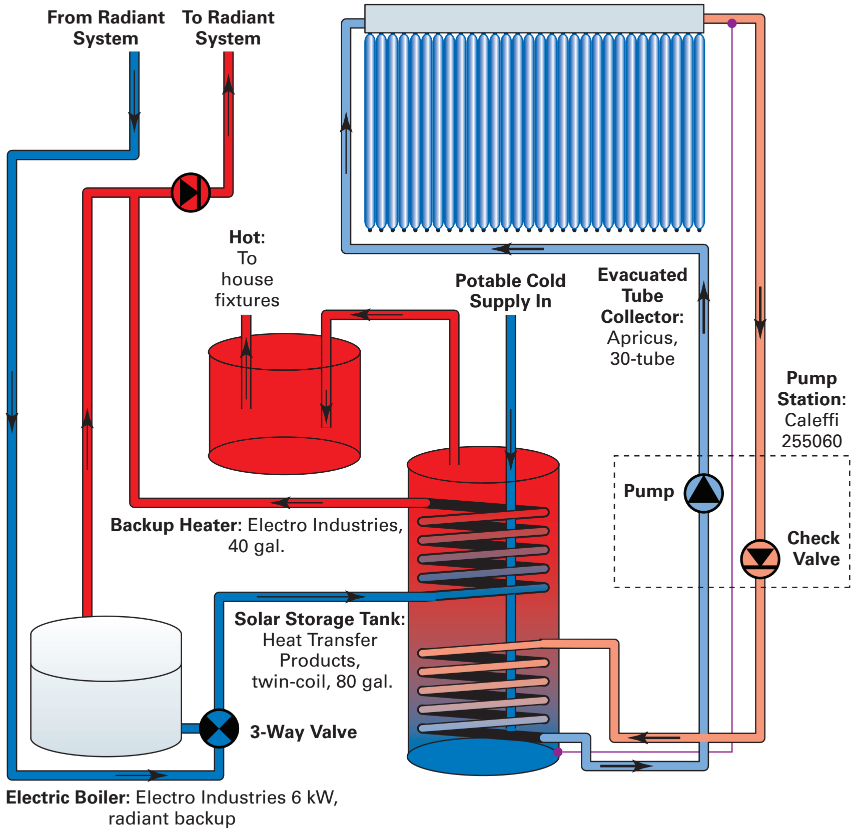
Pressure: Integrated with the Caleffi solar pump station

Courtesy Watts Radiant



The Watts Radiant HydroNex panel is the hydronic system's temperature mixing and control station.

Pinegar Solar Hot Water System



Note: This diagram is greatly simplified and does not show or label all the controls, pumps, manifold, and sensors that are part of the system.


Courtesy www.aillc.biz (3)

This Habitat for Humanity home presents a model of an affordable, modern, and energy-efficient dwelling.

did—the construction launched with more than 300 first-year students prefabricating the exterior walls of the house.

This home was a Drury *community* project, where faculty, staff, and entire classes from various curricula volunteered their efforts. The home became a classroom for all. Each group was given an introduction to the home's sustainable design principles, along with how they could make changes in their personal lives toward environmentally friendly practices.

End Results

Amy Pinegar, her three children, and one grandchild moved into the home last summer. She's thrilled with her Habitat home.

"What is it like to live in my house? Well, it is constantly admired by people visiting the neighbors, or just passing by," she says. "Everyone just loves it! Spring is my favorite time of year—not just because of weather, but the fact that the house has so many windows. No matter what direction the wind is blowing, it flows through the house.

When the sun shines during the winter, it can really heat the house up without the use of the radiant—just natural heat from the sun."

Anna Codutti, director of development for Habitat for Humanity Springfield, looks forward to the home being a model for affordable green-builds nationwide. "It's been an amazing experience working with Drury students and professors to turn the idea of creating an affordable, sustainable residence into an actual Habitat home," Codutti says. "We learned a lot through the process, and I know it meant a lot to Amy that the students were so eager to involve her during all stages of the project."

"This house may look different from the other homes in the subdivision, but it's a great visual representation of what Habitat is trying to do with the community as a whole," added Codutti. "Legacy Trails is a low-impact development, designed chiefly to show developers the affordability and long-term benefits of environmentally friendly infrastructure."

"The residential sector contributes greatly to climate change and is responsible for 21% of U.S. carbon dioxide emissions," said Michelle Moore, an executive with the U.S. Green Building Council. "Green homes like the Drury University project are an immediate and measurable way that individuals can make a difference for the environment—one family at a time."

Access

Manheim, Pennsylvania-based **John Vastyan** (717-664-0535) is a journalist and communications professional focusing on the plumbing, mechanical, radiant heat, and geothermal industries.

Traci Sooter, AIA, LEED AP, (tsooter@drury.edu) is an associate professor of architecture in the Hammons School of Architecture at Drury University in Springfield, Missouri. Formerly a general contractor in Springfield, Traci holds master degrees in architecture and construction management from Washington University in St. Louis, and a bachelors degree in marketing from Missouri State University. She specializes in design/build courses serving charities and communities in need.

Habitat for Humanity • www.habitat.org

Taylor Engineering & Consulting • twtaylorpe@hotmail.com • Energy audit

Mechanical & Electrical Equipment for Buildings, Tenth Edition by Benjamin Stein, John S. Reynolds, Walter T. Grondzik & Alison G. Kwok (2005, Wiley)

System Components:

Apricus Solar Co. • www.apricus.com • Evacuated tube collectors

Caleffi • www.caleffi.us • Solar pump station & accessories

Electro Industries • www.electromn.com • Boiler

Heat Transfer Products • www.htproducts.com • Solar storage tank

Watts Radiant • www.wattsradiant.com • Radiant floor heating components and hydronic control station

Other Products:

Allied Roofing Systems • www.alliedroofingsystems.com • TPO roof

Crete-Heat • www.crete-heat.com • Insulation panels for radiant floor tubing

Shaw Industries • www.patcraft.com • Carpet

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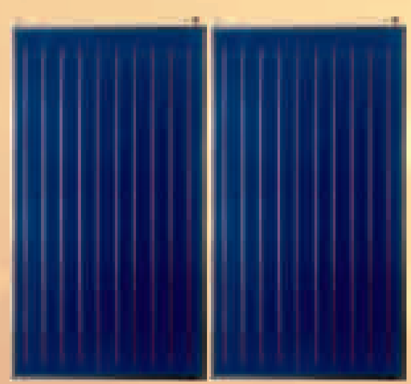

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BEYOND YOUR UTILITY METER

Three Energy Monitors for Your Toolbox

The right tools can help you evaluate your energy usage, cut your utility bills, and curb your electricity use.

Story & photos by Guy Marsden

Way back when, on my way to improving my home's energy efficiency, I made a plug adapter for an inexpensive digital clamp-on multimeter to start identifying the energy hogs in my home. The adapter was an AC plug wired to an AC socket with three accessible wires between. A digital AC meter clamped around the hot wire to measure the current to a particular device. I would read the amps, then multiply this value by 120 volts to get watts. Then, I'd multiply the watts by the number of hours the appliance was on to calculate watt-hours, dividing by 1,000 to get kWh.

This device worked well enough, but it was limited in its scope and application, and could not accurately and over time measure intermittent loads like refrigerators that cycle on and off. Thankfully, consumer products are available to do this job, helping consumers find the energy wasters in their homes.

Watt & Watt-Hour Meters

One of the simplest consumer devices is the watt/watt-hour meter used to measure the power and energy consumption of an individual appliance. The Kill A Watt meter ($20–$50) simplifies the measuring process and adds many great features, such as calculating energy cost and averaging energy consumption over time. The meter plugs directly into a wall outlet, which can make it difficult to read since it may be low on the wall or even plugged in behind the appliance it's measuring. So I typically use it with a short extension cord to make it easier to read. Watts Up? and Brand Electronics meters ($95–$235) are a bit pricier, but are easy to read since they have their own power cord. All of these devices record an appliance's energy use and cost over time, and record accumulated kWh.

This clamp-on ammeter measures current in the conductor it surrounds. Multiplying the measured current by 120 V gives watts.

A Kill A Watt meter plugs directly into an outlet, and measures watts and kWh directly for whatever is then plugged into it.

Data Logging Dedication

But watt-meters only give a small window into a home's overall power use, since they are limited to measuring 120 VAC appliances—they can't accommodate 240 VAC loads—and can only measure one appliance at a time instead of the whole household. (They can measure several appliances if used with a plug strip.) So about four years ago, I bought a HOBO data logger that records information from up to four sensors, such as temperature, voltage, and current. A simple monitoring package runs about $300 (logger, $100; Lite software package, $35; and a couple of current sensors, $90 each). This is a science-nerd tool and requires some patience to set up and get used to. The HOBO is programmed via a computer's USB port and can run for months on its own internal battery. It can record at intervals of 1 second up to 1 day. I have found that a 1-minute interval is fine for electrical monitoring. (I also used it to record temperature data for my solar heating system; see Access.)

The HOBO data logger with current sensors.

I installed the HOBO in my breaker box with the current sensors clamped around each leg of the main power cables. I would download the day's data to my laptop, and use the PLOT function to create graphical views of energy use over time.

Trying to correlate our energy use patterns with the graphed data was like reading a mystery novel. The first thing that I noticed was two "heartbeats" that cycled on and off all day—our two refrigerators. (My wife uses a small under-counter fridge to store fabric dyes for her business.) Other wiggles and bumps in the graph plots were lighting and the well pump (big, short spikes). The HOBO software allows labeling the graphs and customizing them in many ways.

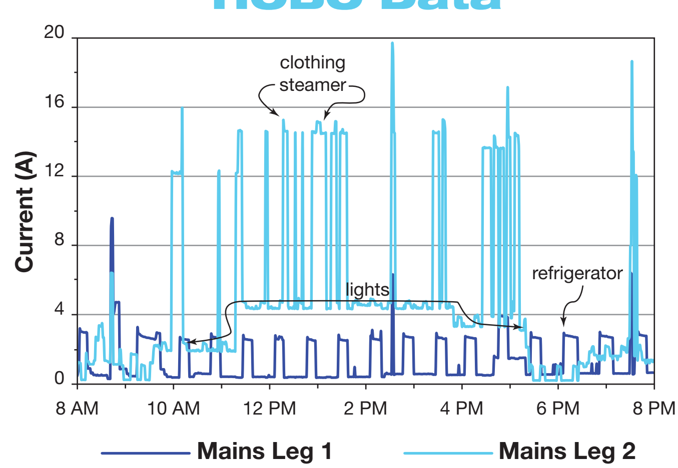
The graphs show a detailed timeline, which you can correlate with specific times of electric usage—and figure out what loads were running. A graph plot that shifts up and remains constant for an hour or more typically corresponds

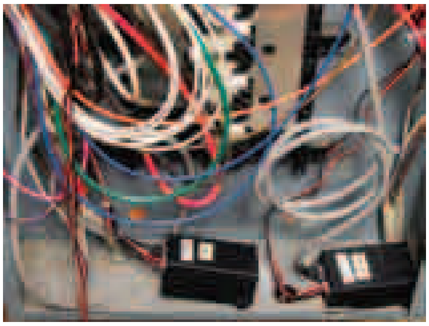
Energy Gotchas & Fixes

My first energy epiphany came when I used my Kill A Watt to measure a digital video recorder (DVR)—it uses about 52 W on standby! It is basically a desktop computer that's on all the time, consuming more than 1.2 kWh each day. To cut its energy use, I plugged it into a timer, which turns it on at 6 p.m. and off again at 2 a.m., and programmed the DVR to dial in and get programming updates at 1 a.m. Each month, this saves 25 kWh. At my local utility rate of 18 cents per kWh, that's more than $50 saved each year!

The timers that I use are digital with battery backup, and cost about $10. They can be programmed to the minute and set for specific days as needed, and have a convenient manual override button. The timers use a miniscule amount of power (0.2 W when the internal relay is off and 0.8 W when on)—the old rotary ones that use clock motors draw about twice as much. Other items I control with timers are the wireless network router, cable modem, decorative lighting, and heat recovery ventilator system.

HOBO Data

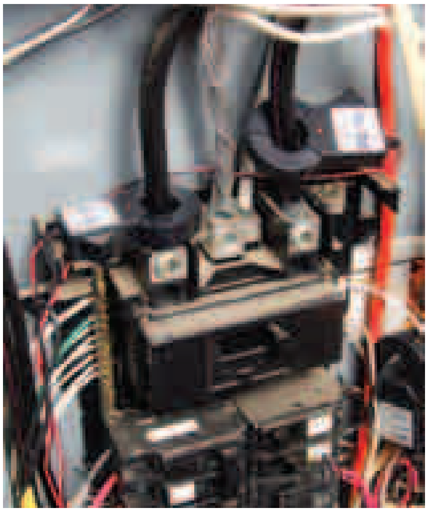




Left: TED Gateway is plugged into the wall, to receive data from its circuit monitors.

Center: TED energy-monitoring units in the breaker box.

Right: The current-detecting clamps, which attach to the energy monitors.



to the lighting load. Electric water heaters typically produce high peaks on a graph. I used my HOBO to help my neighbors identify their big energy hog—a water heater which was constantly cycling throughout the day. I helped them install a timer to shut it off during the day, when they were not home.

Sleuthing with TED

For folks who don't like to fiddle with daily downloads and want a more user-friendly and less expensive interface, The Energy Detective (TED) may offer a simpler solution for whole-house energy monitoring.

The base model TED 5000 ($199) installation is fairly simple: a box sits in the breaker box and wires into a breaker, and two clamps clip over the main electric cables. This energy monitoring unit (EMU) sends signals through the house wiring to TED's Gateway, a small, black box that looks like a wall power supply and plugs into any standard household outlet. This unobtrusive device is a Web server. It also transmits a wireless signal to an optional battery-powered LCD display up to 100 feet away to show real-time stats. But the main feature of the TED system is that you can plug a network cable into the Gateway that connects to your router and see a beautiful energy dashboard with detailed graphs of your home's energy use right on your computer. This only works within your LAN—if you want to monitor your home power from the Internet, you can use the Google PowerMeter (more on that later).

I set up the TED 5000 unit with two sets of sensors so I could monitor incoming utility power and my solar-generated power. The installation was fairly straightforward, but I needed to call tech support to get the solar power graph functions to work properly. The TED screen creates a third line on its graphs for the net energy usage. In the screen shots (opposite page), blue

Energy Savings from Timers & Switched Outlets

Phantom Load Appliance	Hours / Day, if Phantom Load Unswitched	-	Hours / Day Timers or Switches "On"	=	Hours / Day of Phantom Load	×	Phantom Energy Use (Watts)	=	Daily Wasted Energy (Wh)	Average Monthly Wasted Energy (kWh)	Annual Wasted Energy (kWh)	Savings on Grid-Tied PV System Cost*	Annual CO_2 Savings (Lbs.)**
LCD TV, 37 in.	24		6.0		18		1		18.0	0.55	6.57	$39.42	5.65
DVD player	24		6.0		18		4		72.0	2.19	26.28	157.68	22.60
Digital video recorder (DVR)	24		8.0		18		52		832.0	25.31	303.68	1,822.08	261.16
Stereo receiver	24		6.0		18		2		36.0	1.10	13.14	78.84	11.30
CD player	24		6.0		18		2		36.0	1.10	13.14	78.84	11.30
2 wireless routers	24		18.0		6		6		36.0	1.10	13.14	78.84	11.30
Cable modem	24		18.0		6		8		48.0	1.46	17.52	105.12	15.07
Laser printer	24		0.2		24		7		166.6	5.07	60.81	364.85	52.30
Multi-function ink-jet	24		0.2		24		3		71.4	2.17	26.06	156.37	22.41
Amplified speakers	24		0.5		24		7		164.5	5.00	60.04	360.26	51.64
Propane room heater	24		11.0		13		5		65.0	1.98	23.73	142.35	20.40
									Totals	47.01	564.11	$3,384.65	485.13

* Based on a 4 kW system at $8 per W, no incentives included.

** Based on 0.86 Lbs. of CO_2 per kWh (for Maine utilities).

Clockwise from upper left: TED's 24-hour graph, 2-day graph, 13-day graph, and TED's live dashboard display provides real-time data, as well as historical, financial, and weather information.

represents utility electricity used; the yellow is solar energy produced; and the green is net energy consumption. TED's main dashboard page displays real-time data, such as kWh used since midnight, energy used this month, projected kWh usage, and average daily kWh usage, along with cost, CO_2 offset, and more. Graphing tools can display real-time views plotted by the second, minute, hour, day, and month. I find this scalability particularly useful to track down unusual loads—you can watch the real-time graph in "seconds mode" and turn on a light, and the graph line will jump right away.

The TED graphing function allows me to pull up the "Minute Live View" in the morning so I can examine the last 12 hours of nighttime electricity use. By hovering the mouse over the lowest consistent dips (when the fridge is off), I can see the total combined phantom loads—about 0.201 kW (201 W), which I'm still trying to find with my Watts Up? meter. For deeper statistical analysis, the software exports data for spreadsheets.

Google's PowerMeter displays exported PV output as "negative" usage.

Overall, TED is an impressive tool for learning about energy consumption—you become much more conscious of your home as an energy system. It takes a while to learn how to interpret the graphs and correlate them with what lights or appliances are drawing power. Just as with the HOBO data logger, I found the information fascinating but much more user-friendly.

Ogling Google

For checking on your house's energy consumption remotely, Google's new PowerMeter application (free) syncs with TED to integrate with your iGoogle page (www.google.com/ig). Only a few simple steps in the TED user interface are needed to connect it to PowerMeter, which gives you a 48-hour graphical snapshot of your energy usage. However, the low resolution of PowerMeter is more limiting than TED and frankly, a bit disappointing—you just can't dig into the fine details.

However, Google's premise is that by sharing energy information we can all learn how to reduce our energy consumption. For instance, you can share your PowerMeter with other Google users and your data will show up on their iGoogle page for comparison—kind of a "competing with the Joneses" premise. The original purpose was to enable utility companies to send data from digital utility meters to this system and make energy use transparent to their consumers. (At this writing, 10 utilities have partnered with Google; check the Google Web site to see if your utility has joined. Note that TED will work with any utility—it does not interface with the utility equipment.)

Besides seeing how low you can go, PowerMeter lets you monitor your home's energy use from any location with Internet access. An interesting anecdote is the story of a woman who accessed her PowerMeter app on her cell phone on the way to work—and noticed that the power level seemed high by almost a kilowatt. Curious, she returned home to find a toaster oven that had been left on. Its white plastic housing was turning brown and looked like it was ready to catch on fire. Talk about saving the day! This is the type of increased energy awareness that these tools can create.

With or without the PowerMeter, the TED 5000 system is a good investment in a well-designed tool. You can use it to find the energy wasters among family members. Seeing your real-time energy use can help to change patterns of behavior. Family can be encouraged to compete in energy-saving activities—it's all about raising energy consciousness.

What's Your Energy Path?

TED requires a home computer network, but for those less digitally enabled, using a watt-meter can yield good results. With diligence and patience, you can find your entire home's phantom loads and control them with timers or power strips.

Tools like these can help you along the path to savings—both energy and cash. Eventually talking about kWh will be as common as talking about mpg is today. Almost everyone understands automobile fuel economy and can ballpark what kind of mileage their cars get—but people who understand kWh and know how much energy their homes use on a daily or monthly basis are not as common. Think about it—can you rattle off how much energy your home used last month? That can be the frame of reference for improvement—all you need are the tools and information.

Power vs. Energy

If you look at your electric bill, you will see that you are billed by the kilowatt-hour (kWh)—the amount of *energy* your household consumes. One kWh is equal to 1,000 Wh—like running a 1,000 W toaster oven for an hour. "Power" (W) is instantaneous usage, while "energy" (Wh or kWh) is power used *over time.* If you look at the label on an appliance or light bulb, you will see its rated watts—this is the power that it draws at any given moment.

To figure out how much energy an appliance uses, you need to factor in the amount of time it is running. To compute daily kWh, take the wattage and divide by 1,000 to convert it into kW, and then multiply by the number of hours you're using the item during one day.

If the device label shows amps rather than watts, you can use Ohm's law to calculate the power:

Volts × Amps = Watts

An electric heater rated for 10 A at 120 V uses 1,200 W, or 1.2 kW. If left on for 2 hours, it would consume 2.4 kWh (1.2 kW × 2 hrs.).

Many electric bills will also show the monthly kWh used for the last year, and some will show average daily kWh. Pull out your bill and look closely at these numbers, as this is the simplest metric to evaluate energy consumption. For comparison, in 2008, the average electricity consumption for a U.S. residential utility customer was 920 kWh per month. How does your household measure up?

Access

Guy Marsden (guy@arttec.net) documents his passion for living sustainably at www.arttec.net. Guy is a self-taught electrical engineer who develops electronic prototypes for private inventors and small companies.

"Solar Heat Upgrade: Expanding & Improving an Owner-Installed System," by Guy Marsden in *HP119*

Link to energy-monitoring products • http://blog.mapawatt.com/2009/10/07/list-of-energy-monitoring-tools/

Products:

Brand Electronics • www.brandelectronics.com

Google PowerMeter • www.google.com/powermeter

HOBO data loggers • www.onsetcomp.com

iGoogle • www.google.com/ig

Kill A Watt • www.p3international.com

The Energy Detective • www.theenergydetective.com

Watts Up? • www.wattsupmeters.com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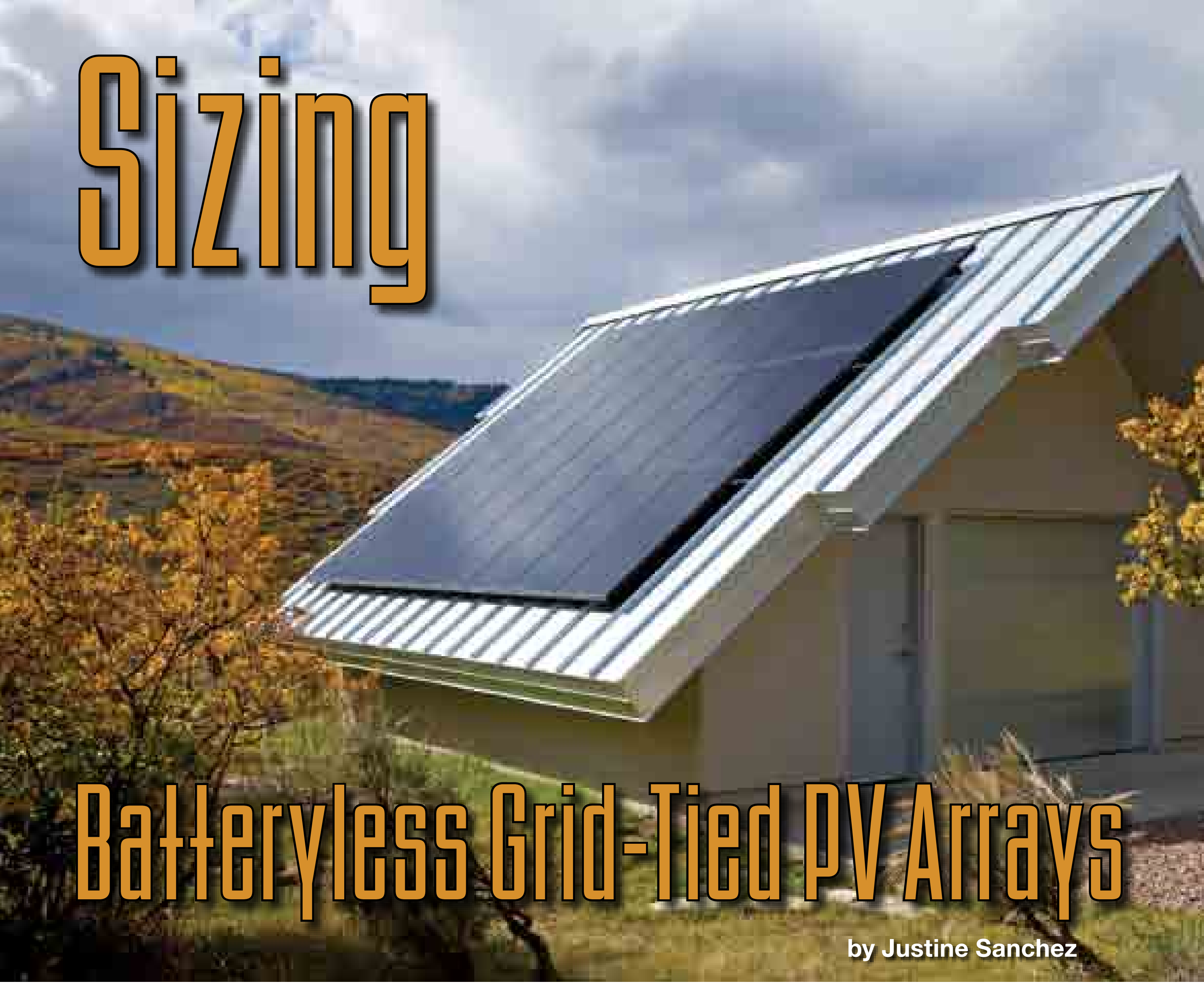
Sizing Batteryless Grid-Tied PV Arrays



by Justine Sanchez

Courtesy www.sunsensesolar.com

Interested in clean power? Check.

Already on the grid? Check.

Are utility blackouts infrequent? Check.

Have a sunny location to mount PV modules? Check.

If this describes your situation, then a batteryless grid-tied PV system could be the perfect fit. Here's how to design your system to maximize production and your return on investment.

Compared to their off-grid counterparts, batteryless grid-tied systems are simple to understand and design, with only two primary components: PV modules and an inverter that feeds AC electricity back into the electrical system to offset some or all of the energy otherwise purchased from the utility. These systems are cheaper, easier to install and maintain, and operate more efficiently than battery-based systems of comparable size. Their main drawback is that when the grid goes down, they cannot provide any energy for you to use.

If the grid is mostly reliable, and outages are infrequent, these systems can offer the best payback for the least price.

Sizing for kWh

The primary goal of a grid-tied PV system is to offset all or some of your electricity usage. Yet the first step in going solar is not sizing the PV system, but reducing electricity usage through conservation and efficiency measures. "Negawatt-hours" are the watt-hours you save by conserving energy—not using it in the first place. The cost of reducing energy use is about 1/3 to 1/5 the cost of producing those same kilowatt-hours with a PV system. Plus, the resulting smaller system means fewer modules, which consume raw materials and energy in their manufacture and shipping.

web extra

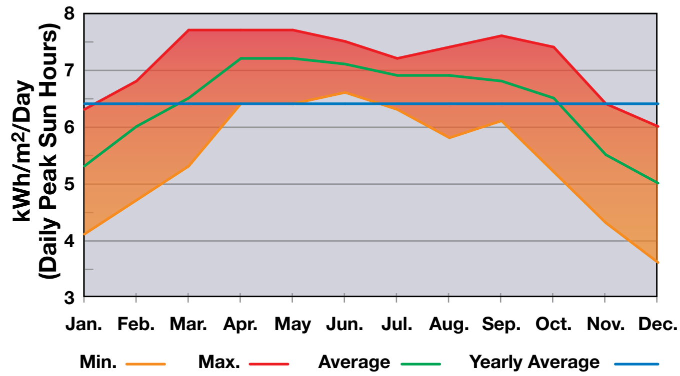
For appliance efficiency tips and strategies, see our Web Extras page: **www.homepower.com/webextras.**

Solar Hot Water & Passive Solar Design

There are many ways to implement solar strategies to reduce a home's energy consumption (both electric and gas). Using a solar hot water (SHW) system to heat the household water is one example. See "Solar Hot Water Simplified" in *HP107* for an overview of SHW systems and components.

If you are building your own home, or considering a remodel, there are many passive solar design strategies that can heat (and cool) your home without any mechanical systems. For example, you can heat or ventilate/cool rooms by simply putting in windows and overhangs in the appropriate places. See "Passive Solar Retrofit" in this issue for more information.

Solar Insolation for Albuquerque, NM



Data: NREL; based on flat-plate collector facing south at a fixed tilt of 35.05° (corresponding to the location's latitude), uncertainty ±9%.

Once energy-efficiency and conservation measures have been implemented, you're ready to size a PV system to offset the remaining energy usage. Annual energy use figures can be requested from your utility, and these values can be used to determine the PV array size. If you've adopted energy-efficiency measures, waiting a full year after their implementation can help you size your PV system more closely to your usage. But you can guesstimate the new annual energy use if you know your consumption patterns and the approximate energy savings for your new energy-efficient appliances. (For example, say you upgrade to a more energy-efficient washing machine—you can calculate the kWh savings per load and multiply that by how many loads of laundry are washed per year to figure out its annual consumption reduction, and then repeat this calculation for all of your upgraded appliances.)

To determine the PV array size needed, you'll also need to know the peak sun-hour figure for your location. Once we have these two values, along with an overall system efficiency factor, a simple calculation can be used to figure the PV array size needed to offset your utility usage.

As an example, let's say we have a home located in Albuquerque, New Mexico. After implementing energy-efficiency strategies, this home consumes 4,000 kWh per year. Using solar data for Albuquerque, supplied by the National Renewable Energy Laboratory (http://rredc.nrel.gov/solar/pubs/redbook/), you'll find the average peak sun-hours per day for a south-facing array, mounted with tilt angle equal to latitude (in this case, 35°) is 6.4. We also estimate an overall average system efficiency factor of 66% (see "PV System Derating").

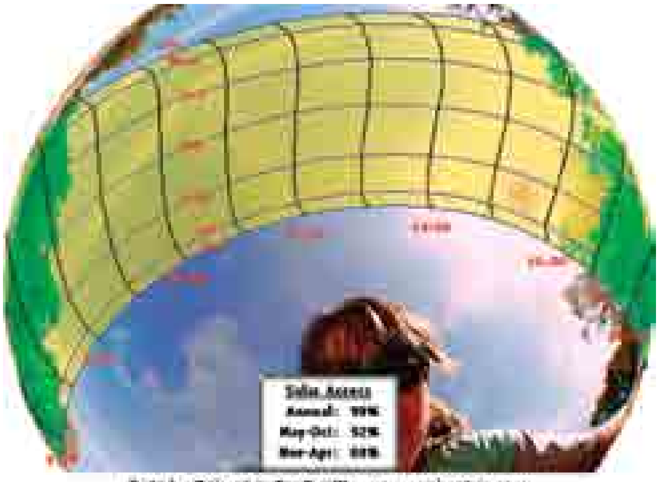
To calculate the array size needed to offset annual energy consumption, divide the annual kWh consumption by 365. This gives an average daily consumption in kWh. Divide this amount by average daily peak sun-hours to get the approximate array size in kW. That value is then divided by the system's efficiency derate factor:

4,000 kWh/yr. ÷ 365 days/yr. = 10.96 kWh/day

10.96 kWh/day ÷ 6.4 sun-hours/day = 1.71 kW

1.71 kW ÷ 0.66 efficiency factor = 2.59 kW array

Several tools, including smartphone apps, are available to help determine your site's solar window.



Data by Solmetric SunEye™ — www.solmetric.com

Array Orientation & Tilt

Generally speaking, nontracking PV arrays in the northern hemisphere will experience the most solar exposure by facing true south at a tilt angle equal to within 5° of the latitude. However, region-specific factors can alter when your array receives the most sunlight. For example, in areas with extremely cloudy winters (like Seattle, WA), a tilt angle of latitude minus 15° can yield the highest annual production for a grid-tied system—summer energy gains at the more shallow tilt far exceed the winter gains at the steeper tilt. Another situation that favors a different array orientation is if your site regularly gets early morning fog. In this case, you will want to shift your array orientation toward the west. See "Optimizing a PV Array" in *HP130*.

To offset 100% of this home's annual electricity consumption, a 2.59 kW system is needed.

However, a benefit of a grid-tied system (as opposed to an off-grid system) is that the system size can be determined by your budget or preference—it doesn't have to be designed to meet 100% of your electrical needs. For example, you could decide to offset 75% of your electricity with a PV array, which would decrease the required system size to 2 kW (2.59 kW × 0.75 = 1.94 kW).

While our example system is located in New Mexico, if our house was in a less sunny climate, such as Eugene, Oregon, which has an average peak sun-hour value of 4.1, we would need a 4 kW array:

4,000 kWh/yr. ÷ 365 days/yr. = 10.96 kWh/day

10.96 kWh/day ÷ 4.1 sun-hours/day = 2.67 kW

2.67 kW ÷ 0.66 efficiency factor = 4.05 kW array

PVWatts Results for Albuquerque, NM

	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
January	5.33	303	$26.36
February	6.06	304	26.45
March	6.44	357	31.06
April	7.16	367	31.93
May	7.40	380	33.06
June	7.10	344	29.93
July	7.13	355	30.89
August	7.02	353	30.71
September	6.71	330	28.71
October	6.55	348	30.28
November	5.73	305	26.54
December	5.14	293	25.49
Annual	6.48	4,039	$351.39

Assumptions: 2.59 kW array, 0.715 derate factor, 35° tilt, south-facing, 8.7¢ per kWh

PV System Derating

There are many environmental factors that can affect how much power a system can produce. These factors are combined for an estimated efficiency/derate value used in array sizing. (For more detail on these individual factors, see "Pump Up the Power—Getting More from your Grid-Tied PV System" in *HP127*.)

An overall average system efficiency of 66% is used in the example calculations to account for the following:

88% derate for energy lost due to module heating (12% loss)

95% for inverter efficiency (5% loss)

97% for DC and AC wiring inefficiencies (3% loss)

95% for module production tolerance and mismatch (5% loss)

95% for module power loss due to dust and dirt (5% loss)

90% shade factor to account for array shading before 8 a.m. and after 4 p.m. (10% loss)

To arrive at 0.66 (66%), multiply all the efficiency factors together:

0.88 × 0.95 × 0.97 × 0.95 × 0.95 × 0.90 = 0.66

While this 0.66 is a general value used for estimating a batteryless PV grid-tied array's size, a derate factor can be adjusted to match each system and site specifics. For the next example, let's say the array will consist of microinverters, which will eliminate losses due to module mismatch, and will use modules that have a positive-only production tolerance. In this case, the module production tolerance and mismatch loss will be zero (or will have an efficiency of 100% for a factor of 1.0), increasing the overall efficiency factor to 69%.

0.88 × 0.95 × 0.97 × 1.00 × 0.95 × 0.90 = 0.69

Conversely, let's go back to the original string inverter and after performing a shade analysis on the roof, we find that the solar window is really from 8:30 a.m. to 3:30 p.m. and the shading factor is 0.85. This will decrease the efficiency factor to 62%.

0.88 × 0.95 × 0.97 × 0.95 × 0.95 × 0.85 = 0.62

Using PVWatts to Size a System

A common approach to array sizing is to use NREL's PVWatts program (www.nrel.gov/rredc/pvwatts/version1.html), an online PV system production estimator. By plugging in various PV array size values (and a few other system specifics), you can find what size array matches your annual energy production goal.

You can also use PVWatts to double-check your manual calculations. Note that you will need to work with the program's "DC to AC Derate Factor" calculator to match your system specifics, such as incorporating the shading factor. You will also see that they have more conservative default values, such as inverter efficiency. Their default value puts inverter efficiency at 92%, but the actual CEC weighted inverter efficiency values for many grid-tied inverters are closer to 95% (see Access).

Although PVWatts' "DC to AC Derate Factor" does not show a specific designation for losses due to module heating, the program automatically incorporates this efficiency loss using regional temperature data and a general PV power loss figure (0.5 % per °C rise) in their kWh production estimates (see the PVWatts help files for more info).

Another handy feature of the PVWatts program is the ability to test the effects of various PV array tilt angles and orientations on energy output. In our example above, the array is sited to face true south and set at a tilt angle equal to the location's latitude. However, there are situations where an array cannot be "ideally" sited or tilted—those parameters can be entered into the PVWatts system specifics to see what the impacts on system production might be. For example, if the example array had been oriented at 225° and at a pitch of 20°, PVWatts would estimate output to be about 8% less than an optimally oriented array. Conversely, PVWatts can be used to find the optimal array tilt angle by entering various angles and noting which one gives the most kWh per year.

Courtesy www.sunsensesolar.com

Sometimes, squeezing the maximum number of modules on the roof takes thinking outside the box.

Sizing within Space Constraints

In residential areas especially, a primary constraint to PV array sizing can be the size of the available shade-free mounting area. PV modules can be mounted on a roof, the ground, or a pole (which includes trackers). Roof-mounting generally takes advantage of underutilized space, but the installation may require penetrations through the roof, and can cause wear and tear on the roofing material while the work is being done. Ground-mounted systems take up yard space that might be preferred for other purposes (garden, etc.) and usually requires constructing substantial concrete footings. But the work can be done on the ground (easier and safer), and eliminates firefighters' concerns about electrical equipment being located on the roof. Plus, ground-mounted systems allow more airflow around the modules for less power loss from module heating. Pole mounting has the same basic pros and cons as the ground-mounted approach, but offers the advantage of raising the array off the ground, mitigating shade issues from snow buildup or nearby bushes. Site specifics will dictate which mounting method makes the most sense for each installation.

Regardless of which mounting method is used, the shade-free area, minus clearance needed for maintenance or roof setbacks required by local fire department guidelines, will limit how large the array can be (see Access). In the case of roof-mounted systems, typically 50% to 80% of a roof plane will be available for mounting PV modules.

When space is a consideration, PV array size can be calculated using module power density (watts per square foot, W/ft.^{2}). Crystalline PV module output averages about 12 W per ft.^{2} and amorphous modules about 6 W per ft.^{2}. Let's say we have 250 square feet of roof space that is appropriate for mounting PV modules.

Crystalline modules: 250 ft.^{2} × 12 W/ft.^{2} = 3,000 W
Amorphous modules: 250 ft.^{2} × 6 W/ft.^{2} = 1,500 W

With crystalline modules, the roof space is more than adequate to fit the proposed array size (2.59 kW). (If amorphous silicon modules are used, the array will offset about 58% of the electricity usage.) Where feed-in tariff (FIT) programs are available—which pay a premium rate for solar-generated electricity—some homeowners will opt to maximize use of their roof space, which in some cases will oversize the array and produce a surplus. Even without access to a FIT program, life changes (such as a new baby and increasing loads of laundry per week) often provide opportunities for using those extra solar-produced kWh.

Sizing by Budget

Often the most confining consideration is budget. Currently, the cost per *installed* watt of residential PV systems typically ranges from \$7 to \$9, which includes everything from modules, inverter, disconnects, racking, wire, and conduit to taxes, shipping, installation labor, and permitting.

At some sites, ground-mounted arrays can take advantage of larger areas and better solar access than roof-mounted arrays.

Courtesy www.sunsensesolar.com (2)

Pole-mounted arrays and trackers get the modules up off the ground, away from shading obstructions like bushes and snow.

Using the same location, let's say there's $10,000 available. Without any federal, state, or local incentives, the array size will be limited to between 1.1 kW and 1.4 kW:

$10,000 ÷ $7/W = 1,429 W
$10,000 ÷ $9/W = 1,111 W

Anyone with a federal tax liability can take advantage of the uncapped 30% federal tax credit, allowing you to increase the budget to $14,286 ($14,286 × 0.30 = $4,286 tax credit) and the system size from 1.59 kW to 2.04 kW—and still be within the $10,000. You'd need to pay the full cost up-front—and have enough tax liability to take the full credit that tax year or enough liability each year to spread the tax credit over several years.

Additionally, many individual states, municipalities, and utilities offer rebates that can further offset a PV system's cost. The Database of State Incentives for Renewables & Efficiency (DSIRE; www.dsireusa.org) organizes incentive programs by state and program type, making incentives easy to research. In New Mexico, for instance, PV incentives include a utility renewable energy credit (REC) of $0.13 per kWh; a personal state tax credit (10% of the cost, capped at $9,000); and a property tax exemption for solar systems. While none of these incentives reduce the up-front cost of the PV system, see the "Impact of PV Incentives" sidebar for how you can recoup your up-front investment and even make money over the system's lifetime.

Impact of PV Incentives

Scenario 1: System sized to meet 100% of electricity needs

At $7 to $9 per rated watt, a 2.59 kW PV system will cost between $18,130 and $23,310. The system is estimated to produce about 4,000 kWh per year.

30% federal tax credit ranges from $5,439 to $6,993

10% personal tax credit ranges from $1,813 to $2,331

Estimated REC payment: 4,000 kWh/yr. × $0.13/kWh × 12 yrs. = $ 6,240 total PNM REC payments

Estimated range of total incentives = $ 13,492 – $15,564

Estimated system cost, after incentives = $ 4,638 – $7,746

We can also consider the savings of the kWh offset at $0.09/kWh over 25 years (common module warranty period):

4,000 kWh/yr. × $0.09/kWh × 25 yrs. = $9,000 additional savings*

Scenario 2: Maximizes roof space; provides a surplus of electricity

A 3.0 kW system is estimated to cost between $21,000 and $27,000. This system may produce about 4,600 kWh per year.

30% federal tax credit ranges from $6,300 to $8,100

10% personal tax credit ranges from $2,100 to $2,700

Estimated REC payment: 4,600 kWh/yr. × $0.13/kWh × 12 yrs. = $7,176 total PNM REC payments

Estimated range of total incentives = $15,576 – $17,976

Estimated system cost, after incentives = $5,424 – $9,024

We can also consider the savings of the kWh offset at $0.09/kWh over 25 years (common module warranty period):

4,600 kWh/yr. × $0.09/kWh × 25 yrs. = $10,350 additional savings*

Scenario 3: Budget system

At $7 to $9 per watt, $10,000 will buy a 1.1 to 1.4 kW system, which may produce about 1,700 kWh to 2,160 kWh per year:

30% federal tax credit will be $3,000

10% personal tax credit will be $1,000

Estimated REC payment: 1,700 kWh/yr. × $0.13/kWh × 12 yrs. = $2,652 total PNM REC payments; or 2,160 kWh/yr. × $0.13/kWh × 12 yrs. = $3,370 total PNM REC payments

Estimated range of total incentives = $6,652 - $7,370

Estimated system cost, after incentives = $2,630 – $3,348

We can also consider the savings of the kWh offset at $0.09/kWh over 25 years (common module warranty period):

1,700 kWh/yr. × $0.09/kWh × 25 yrs. = $3,825 additional savings*

2,160 kWh/yr. × $0.09/kWh × 25 yrs. = $4,860 additional savings*

*Note the kWh offset values are conservative savings estimates that use New Mexico's current average electricity rate of $0.09 over 25 years. Electricity rates are likely to continue their upward climb over this period.

System Scenario Costs

	Meets 100% of Electricity Needs	Maximizes Roof Space (250 ft.^{2})	Budget System
System size (kW)	2.59	3.00	1.1 – 1.4
Annual energy output (kWh)	4,000	4,600	1,700 – 2,160
System cost ($7 – 9 per W)	$18,130 – 23,310	$21,000 – 27,000	$10,000
Federal tax credit (30%)	$5,439 – 6,993	$6,300 to 8,100	$3,000
Personal tax credit (10%)	$1,813 – 2,331	$2,100 to 2,700	$1,000
Renewable energy credit (13¢ per kWh for 12 yrs.)	$6,240	$7,176	$2,652 – 3,370
Total incentives	$ 13,492 – 15,564	$15,576 – 17,976	$6,652 – 7,370
Net system cost	$ 4,638 – 7,746	$5,424 – 9,024	$2,630 – 3,348
Utility savings (9¢ per kWh for 25 yrs.)	$9,000	$10,350	$3,825 – 4,860

The Database of State Incentives for Renewables & Efficiency (DSIRE) is a great place to research rebates, grants, and other financial incentives for installing renewable energy systems.

Choosing What's Right for Your System

Array sizing involves considering several criteria—energy production goals, roof space, and budget realities. Each situation and site, and available incentive programs, will dictate the final PV system size and cost. But once you figure out a few specifics, you can be well on your way to meeting your renewable energy goals.

Access

Justine Sanchez (justine.sanchez@homepower.com) is a NABCEP-certified PV installer, *Home Power* Technical Editor, and Solar Energy International instructor, who enjoys watching her batteryless, grid-tied PV system spin the utility meter backward on sunny days.

Go Solar California • www.gosolarcalifornia.org • CEC weighted values for inverter efficiency

Further Reading:

"PV Safety and Firefighting" by Matthew Paiss in *HP131*

"Take Advantage of Solar Incentives" by Mo Rousso in *HP134*

"Grid-Tied Inverter Buyer's Guide" by Ryan Mayfield in *HP133*

"Stretch Your Energy Dollars" by Joel Davidson in *HP112*

"First Steps in Renewable Energy for Your Home" by Phil Livingston in *HP118*

"Efficiency Details for a Clean Energy Change" by Paul Scheckel in *HP121*

The Passive House

Courtesy: www.passivehouse.us

Strategies for Extreme Efficiency

by Katrin Klingenberg & Mike Kernagis

The Passive House (PH) concept—slashing heating and cooling of buildings by up to 95% over a conventionally constructed home—represents one of today's highest energy standards for homes.

The PH concept is a comprehensive approach to cost-effective, high-quality, sustainable construction. Two goals are targeted: minimize energy losses and maximize passive energy gains. Achieving these goals has led to extraordinary results—a PH uses up to 95% less energy for space heating and cooling than a conventionally constructed house.

What makes a PH so special? Mostly, its extreme attention to detail—using highly insulating materials, as well as high-performance glazing; eliminating thermal bridging; establishing an airtight envelope; and balancing heat/energy recovery ventilation. These strategies can keep a house warm passively—by using existing internal heat sources (people, lights, and appliances) and solar energy admitted by the windows. Even the fresh air supply can be warmed without mechanical intervention by using an earth tube—a passive geothermal heating-and-cooling system.

According to the Architecture 2030 campaign, an average, conventionally built, single-family home in the Midwest uses 14.5 kWh per square foot per year site energy for space conditioning, domestic hot water, and household electricity. A new home built to code has a site energy use of approximately 12 kWh per square foot per year. Homes built to Energy Star standards are about 20% more efficient, at 9.6 kWh per square foot per year. The PH design principles require that a building use no more than 1.39 kWh (4.75 kBtu) per square foot per year for heating and cooling, and that its total source (primary) energy for space conditioning, water heating, and electricity not exceed 11.15 kWh (38 kBtu) per square foot per year based on "treated floor area"—the discounted net-usable conditioned floor area. To achieve these energy savings, designers and builders work together to systematically implement seven principles: 1) superinsulate; 2) eliminate thermal bridges; 3) make it airtight; 4) specify ERVs or HRVs; 5) specify high-performance windows and doors; 6) optimize passive solar and internal heat gains; 7) evaluate and optimize energy gains and losses.

Superinsulate

The insulation applied to a house slows heat transmission and helps maintain the contents at a relatively constant temperature. Warm contents stay warm and cool contents stay cool, even when the temperature on the outside hits the opposite extreme. In a PH, the entire envelope of the building—walls, roof, and floor or basement—is well-insulated. How well-insulated? That depends, of course, on the climate. To achieve the PH standard, the Tahan House, in Berkeley, California, required only 6 inches of blown-in cellulose insulation, while the Skyline House, in the far harsher climate of Duluth, Minnesota, needed 16 inches—almost three times as much. Often, the first feature of a PH to catch a visitor's attention is the unusual thickness of the walls, needed to accommodate the insulation.

PH designers choose from a wide range of materials to create superinsulated buildings, including conventional lumber or masonry construction, double-stud construction, structural insulated panels (SIPs), insulated concrete forms (ICFs), truss joist I-beams (TJIs), or straw-bale construction. Similarly, designers can choose from different types of insulation including cellulose, high-density blown-in fiberglass, polystyrene, spray foam, and straw bale.

Green building goes beyond the energy factor. For example, spray foams have a high R-value and are easy to apply, but they are petroleum-based products and some of the foaming agents contribute significantly to global warming. Manufacturers are seeking to develop spray foams that do not have these disadvantages. Vacuum-insulated panels (VIPs) are a relatively new and pricey option with an exceptionally high R-value per inch. VIPs allow thinner walls, for situations when that is a consideration.

Using maximum amounts of insulation and careful attention to its installation are key elements in achieving a high-performance envelope.

Courtesy: www.passivehouse.us

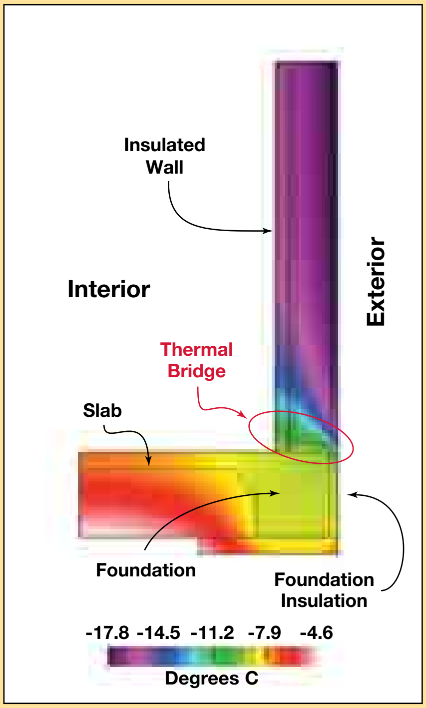
No matter which insulation is selected, it needs to be installed correctly. The application can be inspected and performance measured using thermographic imaging. All objects emit infrared radiation (IR), and the amount of radiation emitted increases with the temperature of the object. Thermographic cameras can measure heat loss, identifying areas where insulation is insufficient, incomplete, damaged, or settled. Thermal images of properly constructed PHs show little heat loss.

Eliminate Thermal Bridges

Heat will flow out of a building fastest via the easiest path, passing quickly through a material that has a higher thermal conductivity—a thermal bridge. Thermal bridges can significantly increase heat losses, which can create areas in or on the walls that are cooler than their surroundings. In the worst-case scenario, this can cause moisture problems—when warm, moist air condenses on a cooler surface.

Thermal bridges occur at envelope edges, corners, connections, and penetrations. A bridge can be as simple as a wall stud with higher thermal conductivity than the surrounding insulated wall or as unsuspected as a balcony slab that is not thermally isolated from an interior concrete floor. Without a thermal break, the balcony will act as a very large cooling fin, sucking heat out of the house in the winter.

In a PH, there are few or no thermal bridges. When the thermal bridge coefficient, an indicator of the extra heat loss caused by a thermal bridge, is less than 0.01 watts per meter per Kelvin (W/m-K), the detail or wall assembly is said to be thermal-bridge-free. Heat loss through this detail is negligible, and interior temperatures are sufficiently stabilized to eliminate moisture problems. It is critical for the PH designer and builder to plan for reducing or eliminating thermal breaks by limiting penetrations, and by using heat transfer-resistant materials. Thermographic imaging can be used to determine how effective the elimination of thermal bridges has been.



Courtesy: Environmental Building news

Make It Airtight

Airtight construction helps the performance of a building by reducing or eliminating drafts—hot or cold—thereby reducing the need for space conditioning. This also helps to prevent warm, moist air from penetrating the structure, condensing inside the wall, and causing structural damage.

Airtight construction is achieved by wrapping an intact, continuous layer of airtight materials around the entire building envelope. Special care must be taken to ensure continuity of this layer around windows, doors, penetrations, and all joints between the roof, walls, and floors. Insulation materials are generally not airtight; the materials used to create an intact airtight layer include a combination of various membranes, tapes, plasters, glues, shields, and gaskets. These materials are becoming increasingly durable, easy to apply, and environmentally sound, which in turn is making it easier for a builder to meet the stringent airtightness requirement of the PH standard.

A home's airtightness provides a measurable dimension of its construction quality. Testing requires the use of a blower door, which is essentially a large, specialized fan that is sealed into an exterior door frame. The blower door can be used to either depressurize or pressurize a house to a designated pressure so a technician can measure how much air is infiltrating the building through all its gaps and cracks. Specific leaks can be detected during the test either with tracer smoke or by examining thermographic images. It is best to conduct the blower-door test at a point during construction when the airtight layer can still be easily accessed and any leaks can be readily addressed.

Courtesy www.passivehouse.us

A blower-door test measures and helps find a home's air leaks.

PHs are extremely airtight. At a standard test pressure of 50 Pascal (Pa), a PH must allow no more than 0.6 ACH (air changes per hour). PHs built from timber, masonry, and prefabricated elements have all met this standard.

Airtightness does not mean that you can't ever open the windows. PHs have many operable windows to take full advantage of natural ventilation to help maintain comfortable temperatures.

Specify Energy or Heat Recovery Ventilation

Perhaps the most common misperception regarding PHs concerns airflow. With the past problems of poor indoor air quality of "too-tight" houses built in the late 1970s and 80s, many builders balk at airtight homes. Even though a PH is "tight," it does breathe. However, rather than breathing unknown volumes of air through uncontrolled leaks, PHs breathe controlled volumes of air by mechanical ventilation, which circulates measured amounts of fresh air through the house and exhausts stale air. The health and comfort of the occupants come first, and good indoor air quality is indispensable.

A PH is ventilated using an energy-efficient, balanced mechanical ventilation system. PHs use energy recovery ventilators (ERVs) or, in cold, dry climates, heat recovery ventilators (HRVs), which incorporate air-to-air energy recovery to transfer from the exhaust air to the incoming fresh air, significantly reducing the energy needed to heat incoming air. State-of-the-art ventilation systems have heat recovery rates of 75% to 95%.

The ventilation system exhausts air from the rooms that produce moisture and unwanted odors, such as the kitchen and bathrooms. Humidistats monitor when moisture levels are elevated, initiating an increase in the ventilation. The exhaust air is drawn through the ventilator, passing through a heat exchanger to transfer the heat to the incoming fresh air. Exhaust air is not mixed with the incoming air—only its heat is transferred.

The ventilator filters the fresh air and removes excess moisture. The system is generally very quiet and draft-free. The PH Planning Package (PHPP; see below) recommends an ACH of 0.3 to 0.4 times the volume of the building, and a guideline for supply air of 18 cubic feet per minute (cfm) per occupant.

The main difference between an HRV and an ERV is that the HRV conserves heat and cooling energy, while the ERV does both and transfers humidity as well. In summer, an ERV helps keep the humidity outside; in winter, it helps prevent indoor air from becoming too dry. For in-between seasons, when no conditioning is needed, a bypass can be installed for either system to avoid heating the incoming air. Alternatively, the ventilation system can be turned off altogether, and windows can be thrown open to bring in fresh air.

Either system's efficiency can be increased by prewarming or precooling the incoming air by passing the incoming air through earth tubes. Since the ground maintains a more consistent temperature throughout the year than the outdoors, passing the air through tubes buried in the earth either preheats or precools the air, depending on the season. Preheating and precooling can also be accomplished indirectly, by circulating water in an underground pipe and using it to heat or cool the air with a water-to-air heat exchanger.

Specify High-Performance Windows & Doors

PH designers choose windows and doors based largely on their insulating value. Low-emissivity (low-e) coatings have significantly affected the heat conductivity of windows. These coatings are microscopically thin, transparent layers of metal or metallic oxide deposited on the surface of the glass. The coated side of the glass faces into the gap between the two panes of a double-glazed window. The gap is filled with low-conductivity argon or krypton gas rather than air, greatly reducing the window's radiant heat transfer. Various low-e coatings allow for high, moderate, or low solar gain to provide a range of options for houses in all climates, from heating-dominated to cooling-dominated. Builders can choose triple-pane low-e-coated, argon-filled windows with special low-conductivity spacers and insulated frames with little thermal bridging. These windows eliminate perceptible cold radiation or convective cold airflow, even in periods of heavy frost.

Courtesy www.quantumbuilder.com

Optimize Passive Solar & Internal Heat Gains

Not only must PHs minimize energy loss, they must also carefully manage a home's energy gains. The first step in designing a PH is to consider how the orientation of a building—and its various parts—will affect its energy losses and gains. There are many issues to be considered: Where should the windows be for maximum sunlight when sunlight is wanted, and minimal heat gain when heat gain is unwanted? The more natural lighting there is, the less artificial lighting will be needed. Designers can enhance residents' enjoyment of available sunlight by orienting bedrooms and living rooms to the south, and putting utility rooms, closets, etc., to the north, where sunlight is not needed.

The right windows, in the right places, make Passive Houses shine. Here, EnerSign's European-certified Passive House windows were used.

Courtesy www.passivehouse.us

PH windows are oriented to take advantage of the passive solar energy, but the goal is not simply to have as much solar gain as possible. Some early superinsulated buildings suffered from overheating, because not enough consideration was given to the amount of solar gain the home received. Good design considers solar gain within the home's overall conditioning needs—and within the budget. Even very efficient windows can lose more heat over a year than they gain, depending on their location, and large windows are expensive.

In the northern hemisphere, windows on the north side receive very little direct solar heat gain, while those on the south can receive a great deal of it. In summer, and especially in cooling-dominated climates, preventing excess solar heat gain is important. This is accomplished by shading the windows, either with roof eaves of the proper length, which block the high-angled summer sun but allow the lower-angled winter sun to enter. Deciduous trees or vines on a trellis can filter out sunlight in the summer but allow it in the winter when the vegetation has been shed. In climates with significant cooling loads, unshaded east- and west-facing windows should be limited and those used should have low-solar-gain, low-e coatings. Otherwise, during the morning and late afternoon, low-angled sunlight can generate a great deal of heat through these windows.

Another, less obvious source of heat gain is internal. Given the exceptionally low heat loss in a PH, heat from internal sources can make a difference. Household appliances, electronic equipment, artificial lighting, and people can all have an effect on heat gain. While designers may not be choosing how many or which appliances will be installed, they often select lighting, and must take into account this heat gain when calculating the overall internal energy gain.

Evaluate Energy Gains & Losses

The Passive House Planning Package (PHPP) is an energy-modeling tool that helps integrate each PH component so that the final design will meet PH requirements. The PHPP starts with the whole building as one zone of energy calculation. The designer inputs all of the house's basic characteristics, including orientation, size, window location, insulation levels, and so on. The PHPP then computes the energy balance of the design. If needed, the designer can change a house's components within PHPP to model the impact of those changes on the overall energy balance. The PH standard is met when:

- the space heating and cooling requirement of the design is less than or equal to 4.75 kBtu per square foot per year (15 kWh/m^2/yr.);
- the primary energy demand of the design is less than or equal to 38 kBtu per square foot per year (120 kWh/m^2/yr.); and
- the airtightness of the building is at or below 0.6 ACH at 50 Pa.

The PHPP also effectively models solar water heating for combined space and domestic water heating, natural ventilation (such as night cooling), and the efficiency of energy recovery ventilation.

Preconstruction modeling of the home's energy performance is an important step in evaluating a Passive House's design.

Specific Demands with Reference to the Treated Floor Area

Treated Floor Area: 506 ft^2

	Applied:	Monthly Method	PH Certificate:	Fulfilled?
Specific Space Heat Demand:	4.43	kBTU/(ft^2yr)	4.75 kBTU/(ft^2yr)	Yes
Pressurization Test Result:	0.6	ACH_{50}	0.6 ACH_{50}	Yes
Specific Primary Energy Demand (DHW, Heating, Cooling, Auxiliary and Household Electricity):	38.0	kBTU/(ft^2yr)	38.0 kBTU/(ft^2yr)	Yes
Specific Primary Energy Demand (DHW, Heating and Auxiliary Electricity):	14	kBTU/(ft^2yr)		
Specific Primary Energy Demand Energy Conservation by Solar Electricity:	162	kBTU/(ft^2yr)		
Heating Load:	7.6	BTU/(ft^2hr)		
Frequency of Overheating:		%	over 77.0 °F	
Specific Useful Cooling Energy Demand:	2	kBTU/(ft^2yr)	4.75 kBTU/(ft^2yr)	Yes
Cooling Load:	4	BTU/(ft^2hr)		

We confirm that the values given herein have been determined following the PHPP methodology and based on the characteristic values of the building. The calculations with PHPP are attached to this application.

Issued on:

signed:

Courtesy: www.passivehouse.us

Up-Front Costs & Energy Savings

Among all the components that contribute to increasing the efficiency of a home's thermal envelope, high-performance windows and doors cost the most. Upgrading from double-pane vinyl-framed windows to high-performance fiberglass windows with insulated frames and triple-pane, argon-filled glazing can cost an additional $10,000 or more for a typical home. Interestingly enough, high-end architectural wood-frame, double-pane window packages upgraded to European high-performance specifications cost only about 10% more.

Costs for a house built to both PH *and* green standards will be 10% to 15% higher than for a house built only to PH standards. In a green-built home, many types of standard materials are replaced, and often these increased costs exceed the costs of energy-efficiency features.

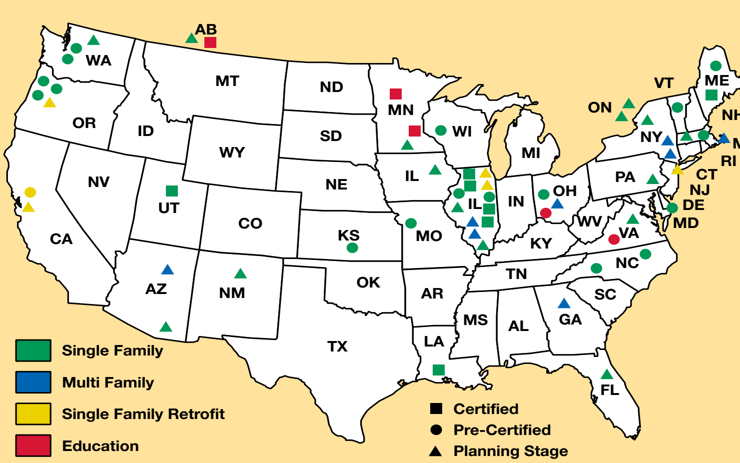
With a focus on energy efficiency and conservation, a PH can get by with a smaller, and therefore less costly, renewable energy system, putting net-zero energy (or even net-positive energy) and carbon-neutrality within reach.

Current Projects

PH projects underway in the U.S. and Canada in the first half of 2010

In April 2007, the Passive House Institute United States (PHIUS) was founded to promote the development of PH knowledge and construction. PH projects are underway in several states and Canada. More than 10 certified PHs have been constructed across the United States and approximately 20 more are in the pre-certification phase (see "Breaking Ground with a PH" in this issue).

Although most PH construction is for new buildings, three pioneering retrofit projects have been completed. Two almost meet the PH standards: one in Berkeley, California, and one in Portland, Oregon; and one is fully certified as a PH in Sonoma County, California.



Courtesy: Environmental Building News

Passive House Certification

Passive House certification is a voluntary process of having energy calculations and details checked by an independent institution to determine if the project was planned and built in accordance with the standards. After construction, a blower-door test is required to prove airtightness; the ventilation system has to be commissioned in a verifiable way; and the general contractor has to certify that the building has been built in accordance with the drawings and specifications verified by PHIUS.

Currently, only a certification path for new construction is available. A retrofit-specific certification with different requirements is planned for late 2010.

From Concept to Reality

In Europe, thousands of homes have been built or remodeled to meet the PH standard, while in the United States, PH design has just begun—but it has the potential to have a dramatic impact on the nation's energy use. Residential energy use constitutes about one-fifth of the total U.S. consumption, and space heating and cooling of U.S. homes represents more than half of a household's total energy use.

Access

Katrin Klingenberg (katrin@passivehouse.us) is the cofounder and executive director of the Passive House Institute US, which promotes the Passive House standard. She designs and consults on Passive House projects across North America, and is a licensed architect in Germany.

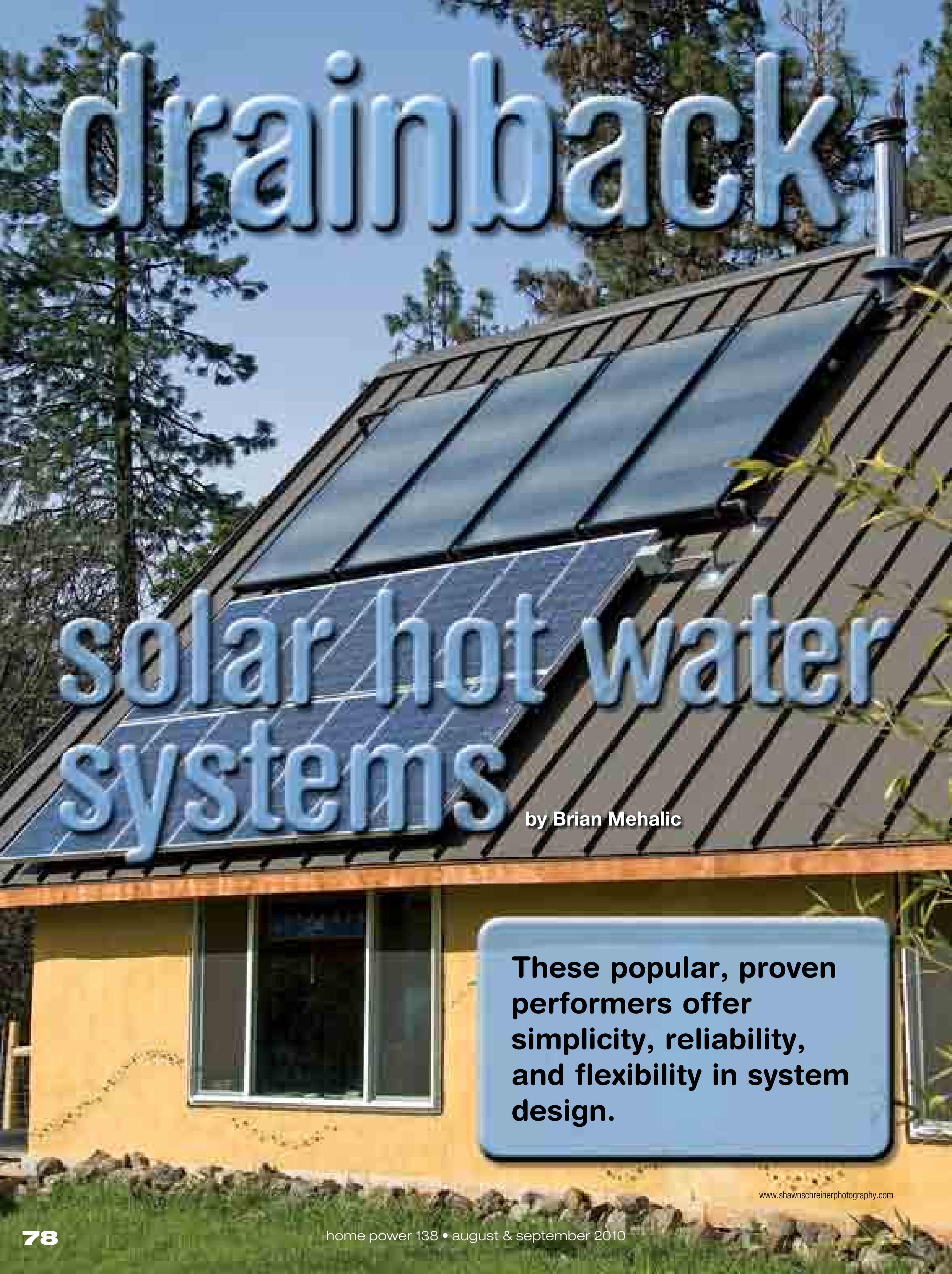
James M. Kernagis (mkernagis@passivehouse.us) is the cofounder and program director of the Passive House Institute US. He was one of the first builders to adopt and build to PH standards, including the nonprofit Ecological Construction Laboratory's building.

Architecture 2030 Challenge • www.architecture2030.org

drainback solar hot water systems

by Brian Mehalic

These popular, proven performers offer simplicity, reliability, and flexibility in system design.



www.shawnschreinerphotography.com

Most locations in North America are subject to at least one freeze per year, making freeze protection necessary for SHW systems. Some systems are pressurized, using glycol or other types of antifreeze to prevent freezing; others, such as the failure-prone draindown and recirculation systems, use motorized valves and additional controls. But the beauty of a drainback system is that freeze protection is passively provided by gravity's ever-reliable pull.

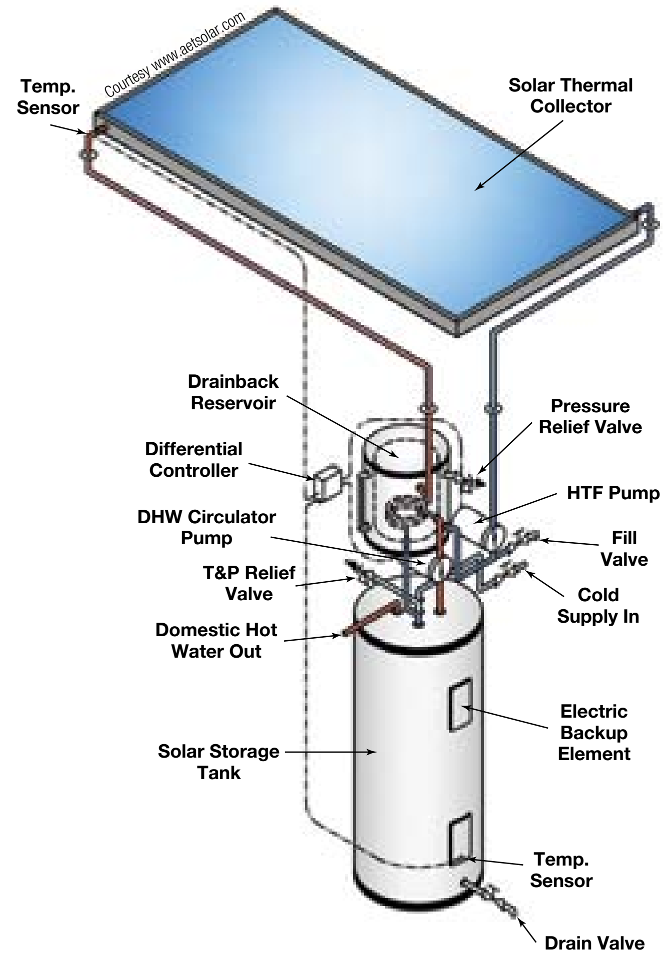
Drainback Details

Drainback systems are closed-loop, indirect, active systems. A heat-transfer fluid (HTF, usually water) contained in an unpressurized, closed loop is pumped through the collectors and is separate from the end-use water being heated through a heat exchanger. When the pump is off, the HTF drains out of the properly sloped collectors and pipe, leaving them empty and protected from freezing.

While this article will primarily focus on residential domestic hot water systems, many options exist for system configurations, ranging from pool heating to space heating and combined domestic hot water and space heating. Regardless of what the heat is being used for, the basic components of a drainback system are:

- A **storage tank**, to hold the end-use water being heated. This could be a domestic hot water tank, a several-thousand-gallon tank for a space-heating system, or, in the case of a pool system, the pool itself.
- One or more **solar hot water collectors**.
- A **differential controller**, which monitors the water temperature in the tank and the collector temperature. When the collector temperature exceeds the storage temperature by a set differential (number of degrees), the controller activates the HTF pump. In some cases, a DC pump, powered by a PV module, acts as the controller—when appropriately sized, the PV module receives enough sunlight to operate the pump when there is enough heat in the thermal collector for it to be worthwhile to circulate the HTF.
- A **reservoir**—a tank in the HTF loop plumbing—which holds the HTF in the drainback/collector loop. The draining of the HTF into the reservoir creates the characteristic gurgling sound of these systems, due to the air space required in the unpressurized reservoir.
- A **heat exchanger** to transfer heat between the drainback loop and the end-use water (unless it is a pool system). The heat exchanger is often inside the drainback reservoir, and a second pump circulates domestic water through the exchanger, which is immersed in the HTF. Most pool-heating systems circulate the pool water through collectors, eliminating the need for a heat exchanger.

Typical Solar Drainback Configuration



Common configuration of a drainback solar hot water system, with two pumps and the heat exchanger integral to the drainback reservoir.

A cutaway diagram of a drainback reservoir with an integrated heat exchanger.

The DBHX 6000 drainback reservoir from Radco comes with an internal heat exchanger, heat-transfer fluid pump, domestic hot water pump, and differential controller.

Efficiency Gains

Regardless of how you heat your water, being efficient and conservative in your usage will reduce your energy bill or the required size of a solar hot water system. Some of the best places to start are:

- Repair leaky faucets
- Install low-flow showerheads and faucets
- Insulate the water heater and hot water piping
- Install heat trap nipples on the water heater to prevent convective heat loss due to siphoning through the plumbing
- Decrease the water heater thermostat setting
- Put a timer on the hot water recirculating pump, if present
- Only wash full loads of clothes and dishes
- Wash clothes and dishes in cold or warm water
- Upgrade to a water-saving front-loading washing machine

Advantages

Drainback systems have many advantages compared to other types of SHW systems. Because it needs an air space in order to drain, the HTF loop is not pressurized. Less stress is placed on solder joints, threaded fittings, and gaskets. If a break occurs in the HTF loop plumbing, it will leak more slowly than if it was pressurized. Furthermore, there are no motorized valves to fail, and the system does not rely on electricity to maintain freeze protection. If the power goes out, the pump shuts off and the HTF drains from the collectors back into the reservoir.

Having an unpressurized HTF loop means that numerous components required in pressurized systems are not needed. An expansion tank, check valve, pressure gauge, and an air vent are not required, though a pressure-relief valve may still be installed. Though any equipment cost savings, might be negated by the expense of the drainback reservoir, installation costs can be lower because the installation is simplified to some degree.

Pressurized, glycol antifreeze systems offer extremely reliable freeze protection. However, these systems are susceptible to overheating. If the pump fails or the system shuts off because it has reached its high limit, the system pressure will increase and can actuate the pressure-relief valve. This can result in the system operating at reduced pressure, requiring additional HTF to be added. Furthermore, glycol can become acidic when repeatedly overheated, risking corrosion to the piping and other components in the system. Drainback systems simply drain the collector because the pumps shut off when the system's high limit is reached.

Drainback systems are often superior for space heating because of that same potential for overheating. Space-heating systems require enough collector surface area to generate useful heat during the coldest, shortest days of the year. But a large system is prone to overheating during the warmer months of the year. During the non-heating season, glycol systems may require covers for some or most of the collectors, a heat dump, a second heat load (such as a pool), some combination of these options, or even draining the system entirely for the season. A drainback space-heating system can safely exceed the recommended collector-to-storage ratio—usually 1:1 or 1:2, depending on the area climate—which means more square footage of collector space capable of producing more Btu in the winter, without the problem of overheating during summer months. The system simply shuts off when the high limit has been reached. Large, combined space-heating and DHW drainback systems can heat water very quickly in the summer when there is no space-heating load and all of the production is focused on the domestic water.

Although some drainback systems use a blend of antifreeze and water for enhanced freeze protection, many use only distilled water as the HTF. Water has superior heat-transfer abilities compared to glycol, adding a slight boost to system performance. Using water as the HTF also allows for the use of single-wall heat exchangers, which are slightly more efficient and usually less expensive than double-wall varieties. The 2009 Uniform Solar Energy Code now allows single-wall exchangers to be used in some propylene-glycol-based systems—but single-wall exchangers are *always* allowed in drainback systems using water as the HTF.

Pipe runs, like this insulated return for the heat-transfer fluid, should slope a minimum of 1/4 inch per foot of horizontal run.

Installation Tips

Piping. To effectively drain (and prevent a vacuum from forming), all piping in the HTF loop must be sloped. A 1/4-inch slope per foot of run is an acceptable minimum, but a greater slope—up to vertical, especially in unconditioned or exterior locations and on the hot return line from the collector—is recommended if possible.

It is also important to adequately support long, horizontal pipe runs. Even if they are correctly sloped at installation, the potential for sagging over time can result in low spots that can impede drainage or allow undrained HTF to freeze. Using one-size-larger-diameter pipe (such as 1-inch, when 3/4-inch could be used on a pressurized loop) and substituting two 45° fittings in place of a single 90° elbow can help ease flow restrictions.

Collectors. The collectors must also be sloped toward the return side, the same 1/4-inch per foot as the piping. This means that on a 4-foot-wide collector, the inlet port should be in a plane that's 1 inch below the outlet port, which is typically located on the opposite edge of the collector. The collector also needs to be tilted—approximately 25°—and should only be flush-mounted on roofs that have a 5:12 pitch or greater. Collectors should be installed so that the longer, narrow, riser tubes run vertically, with the header tubes horizontal. For most collectors, this equates to a "portrait" orientation. This is to reduce the possibility of the riser tubes sagging over time under the weight of the HTF, eventually creating water-trapping low spots in the collector.

Drainback Considerations

Because the HTF is in the reservoir and the collector is empty when the pump starts, the pump has to overcome more static head to lift the HTF from its lowest level to the highest point in the system. This requires a larger pump, using more electricity. For systems with very high head, large-enough pumps may not be available. Some installers will plumb multiple pumps in series, but if one pump fails, the HTF may not make it all the way to the top of the collector and out the return piping, leaving it vulnerable to freezing.

Many drainback systems use a second pump to circulate the end-use water through the heat exchanger in the reservoir, adding to the amount of energy required. A standard, two-pump, residential domestic drainback system can easily use three or more times the amount of power to operate the pumps compared to a single-pump, pressurized glycol system. For example, a pump in a glycol system may use about 85 watts, while the total for the two pumps in a comparably sized drainback system may be 260 watts or more. In some cases, the additional energy required—which could be nearly 2 kWh per day for a domestic system during high-production days—makes it prohibitive to install drainback systems in off-grid applications.

To facilitate HTF drainage from all the plumbing that is exposed to potential freezing—including the collector, exterior piping, and plumbing in unconditioned spaces such as an attic—it is critical that they slope downward to drain. Any low points, whether due to improperly sloped or sagging piping, can trap water, defeating the freeze protection. If the slope is insufficient, a vacuum can result in the HTF loop, which will also prevent it from fully draining. It is recommended that larger piping be used to reduce the head caused by friction, which, for the same flow rate, decreases as pipe size increases. For example, if a pressurized, single-collector system would be plumbed with 1/2-inch pipe; a comparable drainback system should use 3/4-inch pipe.

Even though it is theoretically a closed loop, HTF will evaporate. The drainback reservoir volume should be checked periodically, and topped off if fluid is low. If the volume of HTF is too low, it may result in reduced or even no output, and possibly damage the pump.

Drainback system freeze protection is not fail-safe. Though rare, relays in the differential controller that operates the pump(s) can fail, causing the pump to continue to run and circulate fluid through the piping and collectors. Pipes can sag over time, or may have been poorly installed and improperly sloped in the first place; low spots in the plumbing can trap water and prevent it from fully draining, defeating the freeze protection of the system.

During cold conditions, this puts the system in jeopardy of freezing. Although the actual amount of water released by a freeze-caused leak will be limited to less than the volume of HTF in the system, damage to building materials and contents of the building can occur, and bursting can damage the absorber plate in collectors, requiring potentially difficult and expensive repairs.

A common "fix" for a poorly plumbed or aging drainback system is to add propylene glycol to the water, ranging from 30% to 50%. In cold climates, the system may even be designed to use an antifreeze mix to increase the reliability of the freeze protection. Because the glycol will leave a film inside the collector when it drains, it is very common to see

Benjamin Root

Mounting drainback reservoirs as high as possible within the conditioned space reduces total head, and thus the load on the HTF pump. Proper support is required, as the reservoir and other components may weigh 100 pounds or more, depending on the volume.

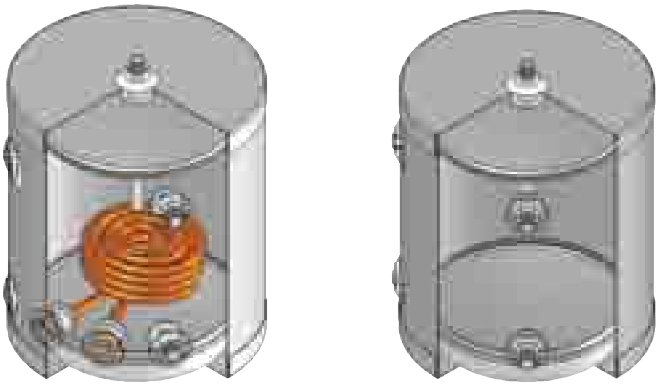
the HTF mix become brown and acidic over time. As with a pressurized glycol system, periodic testing of HTF acidity should be followed with its replacement as needed.

Scale buildup inside the heat exchanger can also be an issue, since minerals precipitate out of water as it's heated. They accumulate on the pipe walls, reducing the heat exchanger's flow and efficiency. Eventually, the heat exchanger may become completely clogged, rendering the system ineffective and causing the motor in the end-use water's circulator pump to overheat. Depending on local water conditions, occasionally flushing the heat exchanger with a chemical descaler or a compound such as muriatic acid may be necessary. Scale buildup can also occur in the collectors, which is why distilled water should be used as the HTF. This is especially critical in systems that lose HTF over time due to evaporation, since this results in mineral deposits being concentrated in the collectors, which is especially problematic for the narrow riser tubes.

Design & Sizing

The drainback reservoir is unique to this type of system. Its capacity should be at least twice the volume of the HTF loop, including the volume of the collectors. It must be able to hold enough fluid so that, when pumping, the pipes to the collectors and the collectors themselves are full. Also, enough fluid must remain in the reservoir to ensure that the HTF level stays above the pump's inlet so that it does not suck air. If air bubbles get stuck in the pump—a condition called cavitation—the pump must work harder to move the fluid. This can cause the pump to overheat, increasing the possibility of premature failure, and cavitation can even completely stop the flow of the HTF. Furthermore, if the reservoir is undersized, the HTF can operate at too high of a temperature, reducing the efficiency of the collectors. If the reservoir is too large, the HTF may operate at too low of temperature, resulting in a poor heat exchange efficiency between the HTF and the end-use water.

If the heat exchanger is located inside the drainback tank, the HTF level must be high enough so that the coil is submerged while the system is pumping. Consult the manufacturers' spec sheets for collector volume, as well as for the recommended system capacity for a specific drainback reservoir. The pipe length and diameter will differ on each installation and can be calculated as shown in the pipe sizing table.



Courtesy www.htproducts.com

Heat Transfer Products offers drainback reservoirs with or without integrated heat exchangers.

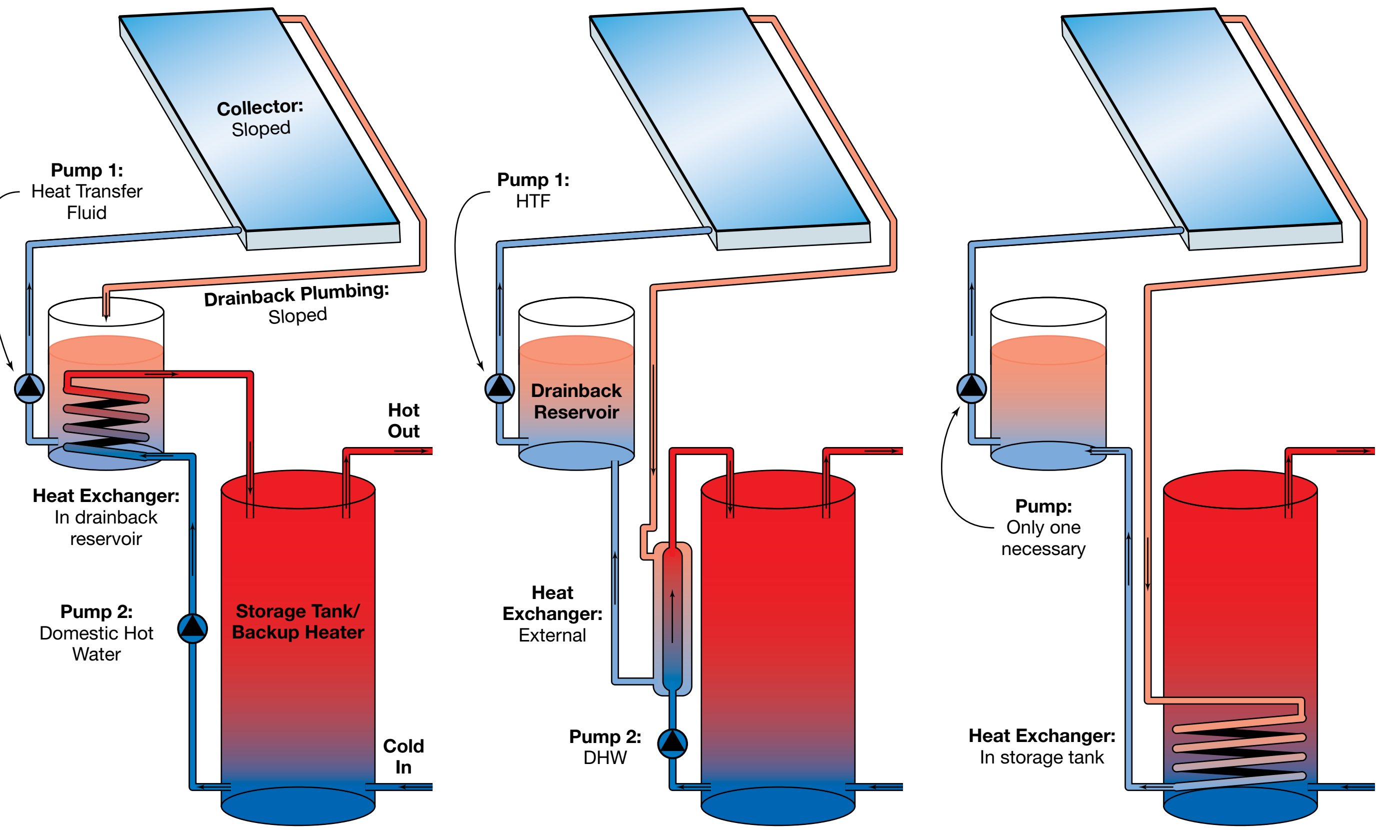
Many prepackaged drainback systems locate the drainback tank on top of the storage tank, which can reduce the head—and thus the pump size—for the system. In some cases, the drainback reservoir is placed in a different location than the storage tank—for example, the storage tank may be in a basement, while the drainback reservoir is on the ground level or second floor. This can dramatically reduce head, but the reservoir must be located in conditioned space to avoid freezing (i.e., not installed in an uninsulated attic).

Drainback System Pipe Size & Volume

	Type L Copper Pipe		Type M Copper Pipe	
Pipe Size (In.)	Pipe Gal. Per Ft.	Min. Tank Size (Gal.)*	Pipe Gal. Per Ft.	Min. Tank Size (Gal.)*
1/2	0.0121	4	0.0132	4
3/4	0.0251	5	0.0269	5
1	0.0429	6	0.0454	7

*For 40 ft. round trip in HTF loop; collector volume 1.2 gal.

Typical Residential Heat Exchanger Configurations



With the heat exchanger inside the drainback reservoir (left) or an external heat exchanger setup (middle), two pumps are necessary: one for the heat-transfer fluid and one for the domestic hot water.

With the heat exchanger inside the storage tank, only one pump is necessary to circulate the heat transfer fluid throughout the whole system.

Access to the fill and drain ports in the drainback tank should be considered when designing the system, so that the HTF can be checked and topped off if needed. A sight-glass can be installed on the HTF loop plumbing, level with the top of the reservoir. This makes it easy to check the HTF level when the system has drained back into the reservoir. Using a transparent flow meter as the site tube allows the flow rate to be verified and fine-tuned if necessary.

Heat Exchanger Configurations

Integrated Exchanger in the Reservoir. Many domestic hot water systems use a separate, special drainback reservoir that contains a heat exchanger. The reservoir tank, typically ranging in size from 7 to 15 gallons, has collector supply and return ports for the HTF loop. A second set of ports connects to the internal heat exchanger and is used to route water from the storage tank to the heat exchanger in the reservoir. This system requires two pumps, which are operated by the same controller. One circulates the HTF, which bathes the heat exchanger through which domestic water is pumped by the second pump. In domestic hot water systems, the two pumps will typically be running at the same time. Larger heating systems with big reservoirs are usually installed so that the pumps can run independently because there will be usable heat in the reservoir after the HTF loop shuts off. Likewise, the HTF loop may have to circulate for a while at the start of the day before there is enough heat in the reservoir for the space-heating loop to circulate.

External Exchanger. Another option, which also requires two pumps, is to use an external heat exchanger and a 10- to 20-gallon electric hot water tank as the drainback reservoir. The electric element is not hooked up—the tank is used to simply hold the required volume to fill the HTF loop when pumping and provide an air space for the system to drain. When the system is operating, the HTF passes through one side of the heat exchanger. The domestic water is pumped through the other side of the exchanger in the opposite, counterflow direction.

Storage Tanks with Integrated Exchangers. Using storage tanks with integrated heat exchangers is another popular drainback option. A separate reservoir is still required for the HTF, but only a single pump is needed to circulate the HTF through the collectors, the heat exchanger immersed in the storage tank, and back to the reservoir, completing the circuit.

Larger space-heating systems often use custom drainback tanks, with options for multiple heat exchangers. A large coil of stainless or copper piping submerged in the reservoir tank is used to transfer heat to the storage water; additional exchangers are used to provide heat to a specific location. A backup heat source, such as a boiler, can provide additional heat to the end-use water, activating automatically if a sufficient temperature is not being attained by the solar thermal part of the system.

Choosing a Tank & System

The selection of drainback tanks and systems is growing. While there is the option of using a standard hot water tank as the reservoir, or to use a storage tank with integrated heat exchanger (with the HTF filling the tank), specialized tanks and even complete, packaged systems are available.

Alternate Energy Technologies, Energy Labs, Heat Transfer Products, and Radco are just a few manufacturers that make drainback tanks for residential applications. Some are complete, plumbed systems with the drainback tank mounted on top of the storage tank, and the pumps and controller included. Most make reservoirs with or without integrated heat exchangers. This allows great system flexibility: the heat exchanger model can be used with a standard, four-port storage tank; the tank-only model can be used with an external heat exchanger/four-port storage tank; or a storage tank with an integrated heat exchanger can be used. Models with heat exchangers typically range in capacity from 7 to 20 gallons; models without exchangers are available in larger sizes. Some feature a built-in sight glass in the reservoir. Smaller reservoirs are capable of being mounted on top of the storage tank, saving floor space as long as enough height is available.

SunEarth's Copperstor drainback tank takes a slightly different approach. Designed to be used with an external heat exchanger or a storage tank with an integrated exchanger, this drainback "tank" is merely a bulge in the plumbing. Comprised of several large-diameter (4") copper tubes plumbed in parallel, the "tank" provides a simple and easy-to-install reservoir available in 5- or 7.5-gallon capacities. The Copperstor tank is heavy when full and, unlike a reservoir tank that sits on the floor or on top of the storage tank, will require more support than that provided by the piping that runs to and from it.

The Taco 009-F is a typical high-head pump suitable for heat transfer fluid circulation to the solar thermal collectors in a residential DHW drainback system.

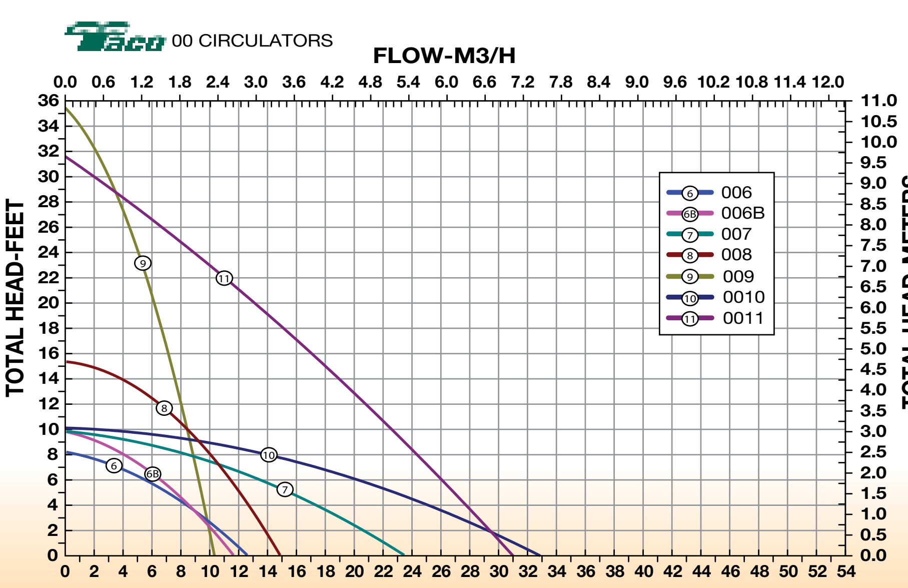
Courtesy www.taco-hvac.com

Trendsetter Solar Products and Morely Manufacturing make large, unpressurized tanks for use in space heating applications or for large-capacity domestic water systems. Various sizes and numbers of heat exchanger loops are available for these large systems.

Choosing a Circulator Pump

In domestic drainback systems, the Taco 009 and Grundfos UP26-64 and UP26-96 are popular HTF pump choices because of their proven durability and ability to lift the HTF 30 feet or more in an unpressurized loop. These (relatively) high-head, cast-iron circulator pumps use more energy than those in pressurized

Example Pump Head & Flow Curves



In an unpressurized loop, head is a combination of the distance between the high and low points in the loop and friction in the plumbing. As head increases, the flow rate a pump is capable of decreases. A flow rate of 1 to 3 gpm is typical for the HTF loop (see spec sheets for the ideal rate).

Courtesy www.taco-hvac.com

Courtesy www.grundfos.com

The Taco 006-BW (left) is a bronze pump, and the Grundfos 15-18 SU (right) is a stainless-steel pump. Both are suitable for domestic hot water loops.

systems. Whatever pump is used, it must allow the reverse flow of the HTF back into the reservoir when the pump turns off; the majority of small circulator pumps do this, but verify that there is not a built-in check valve in the pump (an option in some models), as this will prevent the loop from draining.

If the pump is not adequately sized, it may be able to pump HTF into the collector, but will have difficulty completing the circuit and exiting the collector. During hotter months, this can result in a collector full of HTF that quickly boils and releases steam, reducing the loop volume. As HTF is lost and the loop volume is reduced, it becomes less likely that the pump will be able to complete the circuit, resulting in more steam being produced and more HTF loss. Eventually, the pump will overheat. During colder months, this scenario can lead to burst pipes in the HTF loop or the collector, as the water enters the collector, does not circulate all the way through, and, unmoving, eventually freezes.

When a two-pump system is used, the domestic/storage water circulator must be bronze or stainless steel, because the impeller housing of an iron pump will clog within a few months due to the corrosion caused by the dissolved oxygen in the water. Common choices are the Taco 006 and the Grundfos 15-18 SU, which use much less energy than the high-head HTF pumps, and are easy to service or replace if necessary.

Access

Brian Mehalic (brian@solarenergy.org) is a NABCEP-certified PV installer, with experience designing, installing, and servicing PV, solar thermal, wind, and water-pumping systems. He develops PV curricula and is an instructor for Solar Energy International.

Resources:

"SDHW Installation Basics Part 3: Drainback System," by Chuck Marken & Ken Oldham, *HP97*

"Single-Tank Solar Water Systems," by John Patterson & Suzanne Olsen, *HP124*

"Solar Water Heating Systems Buyer's Guide," by Chuck Marken & Doug Puffer, *HP125*

"Solar Hot Water Storage: Residential Tanks with Integrated Heat Exchangers," by Brian Mehalic, *HP131*

"Pick the Right Pump: Choosing a Circulator for Solar Hot Water Systems," by Chuck Marken, *HP121*

My 3,600 W inverter-charger is overloading my 6,500 W generator—what gives?

Sizing a Generator for Your RE System

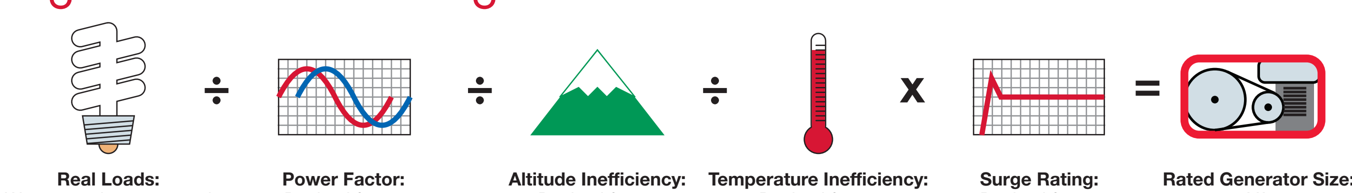
by Jim Goodnight

An 1,800-watt, portable Coleman generator (left) is dwarfed next to a 30,000-watt Cummins/Onan unit (right). Your generator needs will probably fall somewhere in between. But where?

Estimating a system's maximum power load and then specifying a generator to match or slightly exceed the load estimate is a common practice, but one rife with problems. The *apparent loads (volt-amperes)* might be larger than the *real loads (watts)*, environmental factors may have been overlooked, and the generator's specifications and features may not live up to the manufacturer's marketing. Common results include an overloaded generator (and circuit breakers), an unreliable system, a dissatisfied system owner, and tarnished reputations.

This article considers the basics of generator sizing: establishing the load requirements, understanding the difference between apparent power and real power, assessing a generator's environment, and clarifying generator specifications and features. We'll also look at some inverter-charger features that can help reduce part of the peak load on a generator, thus reducing generator size (and cost). Understanding these factors can help you correctly size a generator to reliably meet a system's needs.

Engine-Generator Sizing Process



While some appliances use rated watts as a selling point (for power or efficiency), multiplying the amp rating(s) times voltage will give you the generator's apparent load and peak surge.

Calculate the Apparent Load

The first step is to sum up the power loads that might be operated simultaneously. For this example, let's say the combination of a well pump, a microwave, a fridge, a washing machine, some compact fluorescent lights, and other loads adds up to 3,600 W.

Although we casually tend to express generator power and loads in watts, generator specifications typically state power in volt-amps (VA). This is an important distinction, as a load with a low power factor may not draw many watts, or "real power," but its VA load, or "apparent power," may be higher. For example, a washing machine with a power factor (PF) of 0.5 (the ratio between "real power" and "apparent power") might consume 500 W, but it'll draw about 1,000 VA (120 V × 8.3 A) from a power source.

Here's an example: A 500 W load with a 0.5 PF will draw 500 W ÷ 0.5 = 1,000 VA. 1,000 VA ÷ 120 VAC = 8.33 A. If the PF was 1.0 (i.e., purely resistive), the load current would be (500 W ÷ 1.0) ÷ 120 VAC = 4.17 A.

It's the 1,000 VA's 8.3 A that count against the generator's current limit, not the 500 W. As a result, the generator is required to supply more current to meet the high apparent power demand.

The power factor of common loads varies from quite low (i.e., about 0.5 for the washing machine), to high (i.e., 1.0 for a resistive load). Applying an average power factor of 0.85 to a group of typical loads is a reasonable rule. In our example, the original 3,600 W peak "real load" estimate translates to an apparent load of about 4,300 VA (rounded up to the nearest hundred).

Compensate for Environmental Factors

A generator's power rating is based on its operation at sea level. Generator engine power decreases as altitude increases (thinner air), and a generator's maximum electrical output drops accordingly. A power loss of about 3.5% per 1,000 feet of elevation gain is typical for gasoline-, diesel-, or propane-fueled generators; natural gas-fueled generators may suffer a power loss of about 5% per 1,000 feet. Additionally, the generator's carburetor may need to be modified for high-altitude operation, even to achieve the reduced power rating.

Ambient temperature is a related complication, as typical power derating is about 1 to 2% for each 10°F above its

This engine generator displays its continuous power output rating of 5 kW and its surge capability of 6,250 W. For volt–amps, you'll need to check the documentation.

Power Factor

An AC system's power factor (PF) is the ratio of the load's real power to its apparent power. PF is frequently expressed as a percentage (i.e., 0.8 PF = 80% PF).

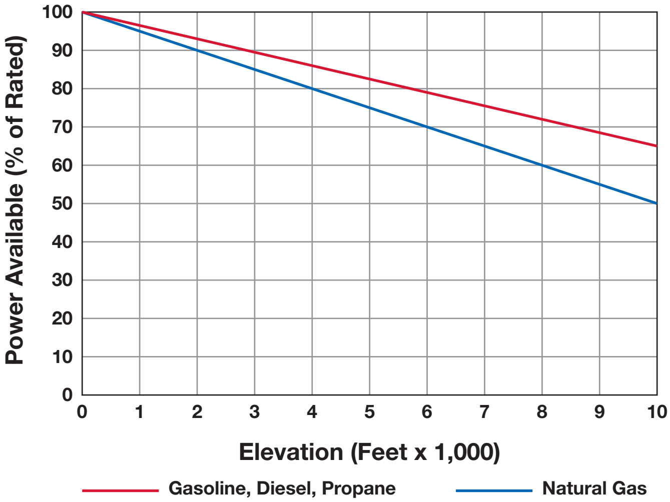
Reactive loads—ones that contain capacitors and/or inductors, such as electric motors—store part of the energy supplied to them, and then return it to the power source. This energy is in addition to the energy used to operate the load, and it results in additional current flowing back and forth between the power source and the load.

Real power is the circuit's capacity for performing work over a particular duration. *Apparent power* is the product of a circuit's voltage and current (volt–amps; VA).

A washing machine can have a fairly low PF (about 50%). Contrast this with a PF-corrected battery charger, which can have a PF of about 98%.

In an electrical system, a load with a low PF draws more current than a load with a high PF, for the same amount of useful power transferred. The higher currents increase the energy lost in the distribution system, and require larger wires, among other things. And, since generators are current-limited power sources, and the low PF loads draw relatively high current, less current is available to power other loads, thereby effectively reducing the generator's functional capacity.

Engine Generator Efficiency at Altitude



nominal rating. Combining the conditions of high altitude and high temperature may require specifying a generator with a higher continuous rating. For example, say you're in Denver, Colorado (elev. 5,000 ft.), and need a propane generator to deliver 4,300 VA during the summer days with temperatures at 90°F. Compensating for altitude would result in a 17.5% loss. If a generator's "full" power specification is based on an ambient temperature of 60°F, then available output can be expected to decrease by about 3% at 90°F [(90°F - 60°F) × 1% ÷ 10°F]. So the actual rating needed would be about 5,400 VA.

Allowing for Surges

Lastly, generator power specifications also emphasize their "surge" capacity, or the VA that can be delivered for 30 minutes or less. This number tends to be about 20% higher than a generator's continuous VA rating. In this example, a 5,400 VA requirement may necessitate a generator with a surge rating of about 6,500 VA. However, this surge capacity can come in handy when starting motorized loads, whose start-up surge current is often several times the normal running current specification.

So even starting with a 3,600 W load, it's not unusual to need a generator rated for at least 6,500 VA, especially if the loads have low power factors and are operated at high elevation.

While full generator output (7,200 W) can be accessed from the 120/240 VAC, 30 A round receptacle, using the 120 V, 20 A receptacles reduces available output to 4,800 W (2,400 W from each).

Other Considerations

Attention to system voltage, split-phase load balancing, and ratings for circuit breakers and outlets may be required to optimize generator size and performance.

RE systems that operate 120 VAC loads generally require a 120 VAC generator, and systems that operate at split-phase 120/240 VAC typically need a 120/240 VAC split-phase generator. However, there are times when a different configuration needs to be considered, perhaps because an old (but still serviceable) generator is available. For example, a 120/240 VAC split-phase generator can be used to power a 120 VAC system by wiring an autotransformer to the 240 VAC generator output.

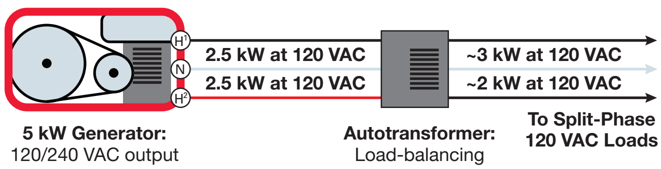
An autotransformer will allow a 240 VAC generator to power 120 VAC loads, or vice versa.

One-half of the total power available from a 120/240 VAC split-phase generator is available from each leg. But too many loads connected to one leg may overload part of the generator—even though the total load is less than the generator's rated power. An autotransformer connected between full, 240 VAC output and the loads will balance the load across the generator's 120 V legs. Popular autotransformers are available from Schneider Electric (formerly Xantrex), OutBack Power Systems, and others.

Sizing for Battery Charging

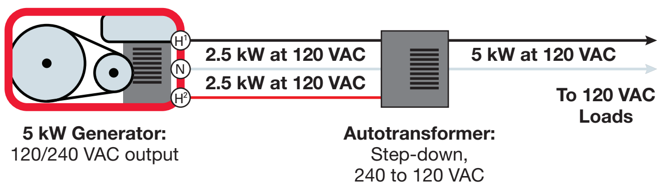
A critical load to consider when sizing a generator for an off-grid system is an inverter's built-in battery charger. Assuming 85% efficiency and a 95% power factor, a battery charger rated at 25 amps DC delivering 1,450 W to a 48 V nominal battery

Balancing High/Uneven Loads Across a Split-Phase Generator Output



Current-limit settings on an inverter–charger allow maximum use of generator output without overloading.

Full Output at 120 VAC with an Autotransformer



bank (charging voltage is actually 48 V) equals a 1,800 VA load. Adding this load to a peak combination of essential loads can dramatically increase a generator's size calculation.

Carrying the example through, adding 1,800 VA to the original 4,300 VA load estimate results in a new estimate of 6,100 VA. Applying the same deratings and surge multipliers, the revised generator "rating" is increased to 9,200 VA!

At the high end, a 9,200 VA generator could simultaneously meet projected load demands and operate the battery charger at full capacity, leading to reduced generator run-time and less noise. However, because peak loads (i.e., microwave ovens) can be short duration and charging loads taper off as the battery fills, much of a large generator's capacity may go unused, reducing its fuel efficiency. Large generators are also relatively expensive.

Generator Sizing Example

	Factor	Adjusted Loads	Loads with Battery Charger
Peak real power estimate		3,600 W	3,000 W + 1,450 W
÷			
Power factor adjustment*	0.85	4,300 VA	6,100* VA
÷			
Altitude derating	3.5% per 1,000 ft. 5,000 ft. = 0.825	5,212 VA	7,394 VA
÷			
Temperature derating	1% per 10° over 60°F 90°F = 0.97	5,373 VA	7,623 VA
x			
Surge rating	120% = 1.20	6,448 VA	9,148 VA
=			
Generator rating		6,500 W	9,200 W

* 0.95 power factor × 85% efficiency = 0.81 for battery charging through an inverter: 1,450 W ÷ 0.81 = 1,800 VA; 4,300 VA + 1,800 VA = 6,100 VA

At the low end, a 6,500 VA generator could meet projected AC load demands, but operating the battery charger at the same time could create an overload. Fortunately, some inverter–chargers include useful features to manage such a load combination. For example, built-in chargers typically include settings that can limit battery charge current to reduce the charger's load.

A more sophisticated tool is an inverter-charger's AC source input current-limit setting, which limits the total current that will be drawn from the generator. If the sum of the home's AC load current and the charger's AC current exceeds the setting, the charger "backs off" the AC current it draws. In effect, the charger becomes a variable, "opportunity" load.

This solution allows a smaller, less-expensive generator to be used, although battery charging time (and therefore generator run time) will likely be increased due to the lower battery charge current. For example, if the household loads draw 30 A (AC) and the charger is set to draw 25 A, but the input current limit setting is 30 A, the inverter will reduce the charger load from 25 A to 0 A to keep the *total* load current at the limit setting. However, if a 15 A load is turned off, reducing the downstream AC load total from 30 A to 15 A, the inverter will automatically increase the charger load from 0 A to 15 A, and the generator's total load current will still be at or below the 30 A input limit.

Choosing a Generator

Understanding how to accurately estimate VA requirements, accounting for environmental factors, and knowing how to work with generator ratings and inverter–charger settings can help ensure that a generator can provide the power needed for your system. A little up-front computation will save you dollars (and headaches) in the long run and ensure that you buy right from the get-go.

Access

Jim Goodnight (james.goodnight@us.schneider-electric.com) has more than 35 years of design and project management experience in a broad range of technical fields. He has been designing and optimizing PV systems since 2002, and providing technical and field support since 2004. In 2010, Jim joined Schneider Electric as a senior sales application engineer.

MMP Installation is Simple As

Mount the Backplate
Mount the BP-MMP backplate to the wall on 16 inch centers. The back plate is 16 ga. powder-coated steel and features ¼-20 pemnuts for fast installation of the inverter and MMP enclosure.

Install the MMP Enclosure
Start four of the supplied ¼-20 bolts into the pemnuts to mount the MMP enclosure. Four mounting keyholes allow you to simply place the enclosure over the bolts and tighten them without having to support the enclosure during installation.

Install the Inverter
Place the inverter/charger on top of the enclosure and secure with supplied bolts. The enclosure supports the weight of the inverter/charger, allowing one person to install a 60 lb inverter/charger without help. The DC positive and negative buss bars are preinstalled, connecting the DC once the inverter is in place. Connect the AC input and output wiring, battery cables, and optional DC breakers.

Attach the optional ME-RC or ME-ARC remote control to the front cover, install the front cover, and you're done.

MAGNUM ENERGY

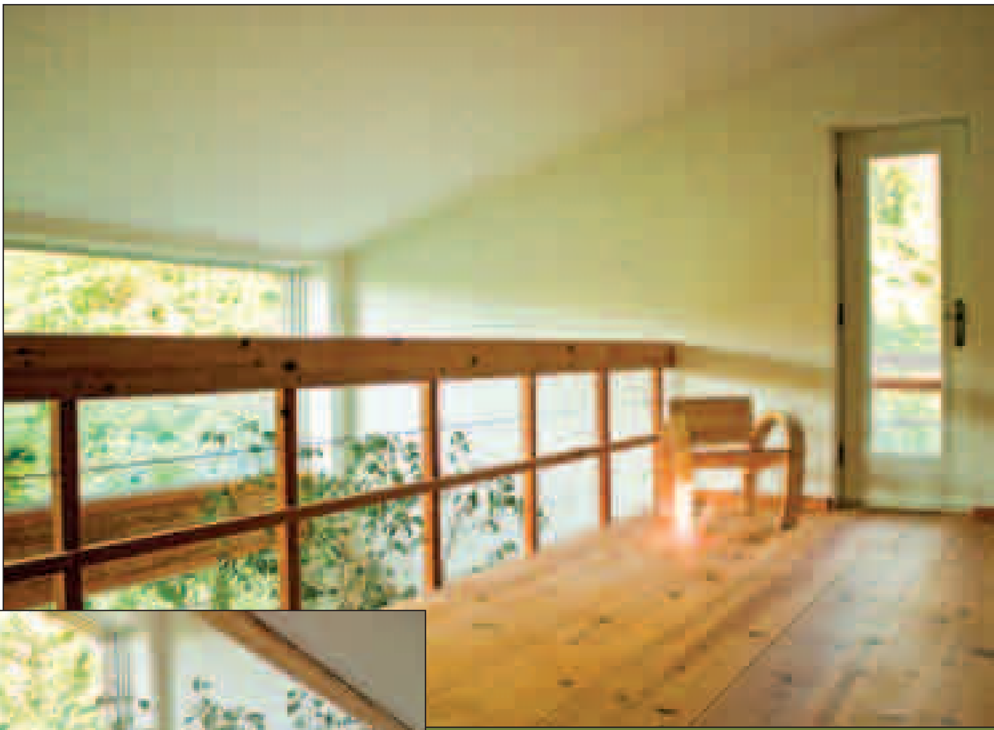
To learn more about the MMP and other Magnum products visit www.magnumenergy.com

Breaking New Ground - with a - PASSIVE HOUSE

by Katrin Klingenberg & Mike Kernagis

Constructed in 2002–2003, the Smith House was the first house built in the United States using the specific practices, technologies, and energy-modeling tools developed by the Passive House Institute.

Led by Katrin Klingenberg, architect and founder of e-colab, an Urbana, Illinois, nonprofit specializing in energy-efficient design, the Smith House design tackled several goals. First was to reduce its operational energy use to one-tenth of a conventional home of the same size in the region. Second was that the design needed to consider lifetime consequences of product choices: all the house's components had to be high in recycled content, and they needed to be reusable or recyclable at the end of the home's useful life. Third, building materials were considered based on their environmental impact. This meant purchasing local, sustainably harvested wood products and locally manufactured building products whenever possible. Finally, since she would occupy the house, Klingenberg wanted to ensure that the house would help minimize her personal environmental impact. To reduce travel-related emissions, Klingenberg chose a site near a bus stop and that was close to the city where she works.



Courtesy: www.passivehouse.us (3)

Careful attention to details, such as orientation for passive solar gain, optimal window placement and sizing, and an open floor plan help the Smith House achieve its energy-efficient performance.

Opposite, left: Large, south-facing windows let in lots of sunlight in the winter, where it's absorbed by the thermal mass floor. In the summer, vines growing over an arbor shade the windows.

Above & left: Open to the floor below, the loft space is easily heated through convection and ventilated by upper windows in the north wall (not pictured).

Design Specifics: Shape & Orientation

The Smith House's simple, compact shape reduces energy losses through its roof and walls because of its small surface-to-volume ratio.

Although the home's shed roof slopes toward the south, which is contrary to traditional passive-solar design, this orientation was chosen to provide the maximum solar exposure for a future PV system. And this shape resulted in additional useful interior space—a loft above the living room.

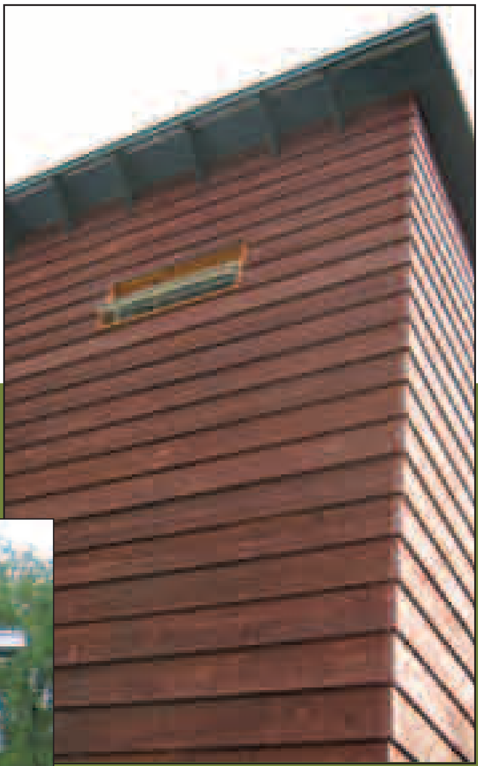
For optimal solar heat gain in winter, the Smith House is oriented due south (although up to 30° away from true south is acceptable for a Passive House—see page 70 in this issue), and all windows on the south façade have a solar heat gain coefficient (SHGC) of 0.61. In the summer, overhangs and a trellis provide exterior shading to prevent unwanted solar gain from increasing the cooling load.

Windows facing east and west are more important to shade in the summer than windows facing north and south, because they are exposed to hours of low-angled sun. Overhangs cannot block sunlight coming in at a low angle; only vertical exterior shading will do so. To minimize unwanted solar gain and overheating in the summer, the windows on the east and west sides of the Smith House are kept to a minimum, and those windows have a low SHGC.

Most of the windows in the Smith House are operable to take full advantage of the wind for natural ventilation in the warmer months. Windows placed high up on the north side of the house give warm air an easy exit, when the mechanical ventilation is turned off.

Construction Details

Insulation. Climate and location determine the appropriate amount of insulation for a Passive House. First to consider is an area's winter design temperature—the lowest temperature that an area generally experiences. Urbana has a winter design temperature of -3°F, considerably lower than that for Berlin, Germany, at 7°F, and Paris at 22°F, for example—climates for which many Passive Homes have been designed and built. However, with abundant solar radiation, Urbana has a climatic advantage that makes the design of a Passive House a bit easier compared to cloudier locales. With these climate factors, Klingenberg determined that the Smith House required a superinsulated envelope on all six sides of at least R-56.



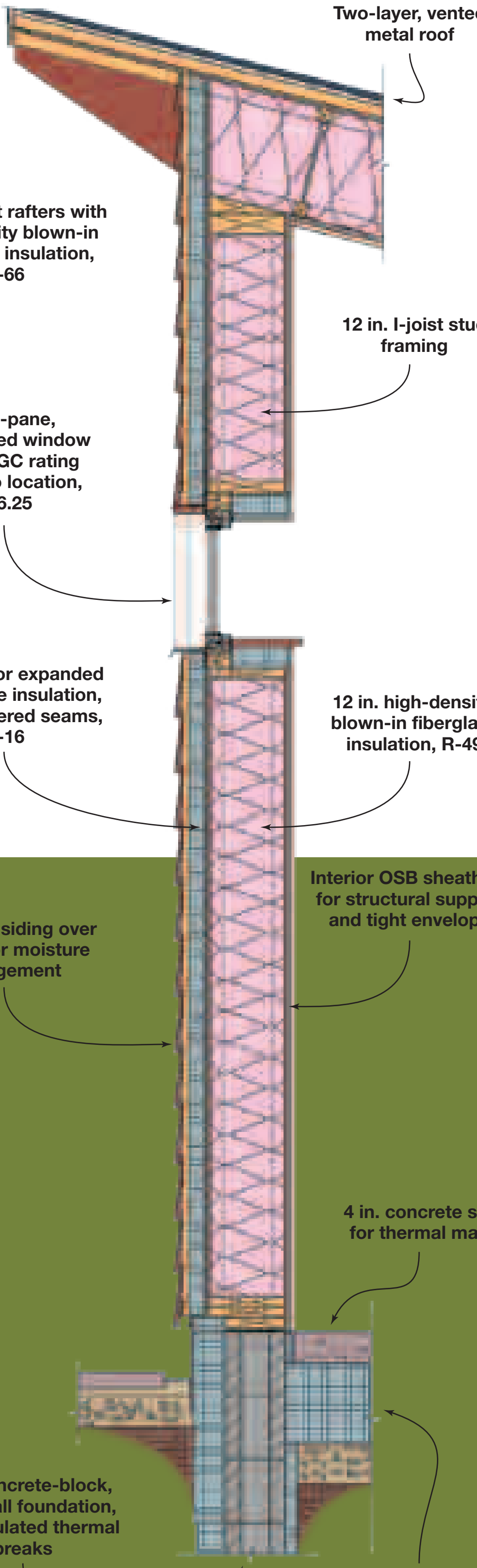
Courtesy: www.passivehouse.us (5)

The vaulted ceiling and thermal mass in the floor (above), plus windows placed high on the second floor (right), increase convection for passive cooling in summer.

Left: An expanse of south-facing, high solar heat gain windows allow the sun's heat to enter in the winter. In summer, an elegantly simple solution—vines trained to grow over the arbor—shades the first-floor windows.

Twelve-inch I-joist wall studs were balloon-framed, minimizing thermal bridging and allowing for the prescribed amount of blown-in fiberglass to be installed.

Construction Details



Foundation. The foundation of the Smith House is a concrete-block frost wall surrounding a floating 4-inch concrete slab, which was left exposed on the interior for thermal storage. The frost wall is insulated around the perimeter with 6 inches of expanded polystyrene (EPS), with 14 inches of EPS under the slab. EPS was chosen over extruded polystyrene (XPS)—the type of expansion agent used at that time in XPS depleted the ozone layer and contributed to global warming. All available research showed that EPS would perform appropriately below grade.

The use of 16-inch I-joist rafters enabled the roof to be insulated to R-66 with blown-in fiberglass.

Four inches of exterior EPS foamboard bring the total wall R-value to 56. Having few east- and west-facing windows minimizes unwanted heat gain and loss through the envelope.

Thermal bridging has largely been avoided due to the minimal thickness of the OSB that connects both flanges from the inside to the outside. Additionally, the TJIs are thermally broken on the exterior by 0.5-inch-thick structural fiberboard and 4 inches of EPS insulation. Penetrations through the exterior envelope are minimized to reduce air infiltration. Utilities and ducts enter the house from under the slab. Electrical installations, switches, and outlets along exterior walls are all surface-mounted or located in the floor to avoid penetrations through the exterior airtight layer. Conduit for a future PV system also enters the house from underneath the slab.

The plumbing vent stack is capped in the attic with an air admittance valve, a small vacuum cap that makes it unnecessary to install a vent stack above the roof, which would require a penetration. (Note that not all state plumbing codes allow using this valve.)

Walls. The walls of the envelope are balloon framed, using 12-inch engineered I-joists. The cavity is filled with high-density blown-in fiberglass insulation. An interior, structurally required sheathing of oriented strand board (OSB) serves as an airtight layer and a vapor barrier, since it has a permeability (perm) rating below 1. In addition, the Smith House is wrapped on four sides in two 2-inch layers of EPS, with the joints staggered. Another layer of 1- by 4-inch pine creates a vent space and doubles as a rain screen façade underneath the final layer of cedar lap siding. The roof framing is 16-inch engineered joists filled with high-density fiberglass insulation, topped by a vented metal roof.

Wall cavities tightly packed with insulation help achieve a high-performance envelope.

Windows. Windows are triple-pane and argon-filled, with low-e coatings specific to their location in the house. The insulated fiberglass window frames contribute to the overall thermal performance of the walls. All windows and doors have multipoint locks to ensure that they seal tightly when they are closed. Their overall airtightness was measured with a blower-door test at 0.52 ACH compared to 5.0 of an average conventional house. With an R-value between 6 and 8, all the windows, even the ceiling-height, south-facing ones, have a sufficiently warm inner surface to eliminate drafts caused by convection—so there is no need to place a heat source or supply vent directly under the window.

Passive House Mechanics

The central component of the mechanical system is a 90%-efficient heat-recovery ventilator. This European HRV has a computer-controlled summer bypass for the shoulder seasons when heat recovery isn't desired. It exchanges the air in the house at a constant low flow, delivering air to the bedrooms and living rooms and exhausting air from the kitchen and bathrooms. The ventilation system has an integrated 1,000 W electric heater so no centralized, separate heating system is needed.

In winter, when the windows in the Smith House remain closed and the mechanical ventilation is working, stratification is noticeably absent. Temperatures on the second floor of the Smith House were measured in the winter and found to be lower than temperatures on the first floor. This is the opposite of what happens in most conventional homes and what one would expect, given that hot air rises. A core principle of a Passive House is insulating the walls, floors, and windows to a level that the surface temperature difference of exterior

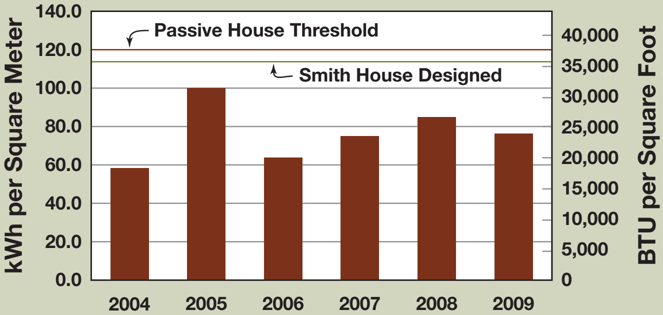
By the Numbers

These are the final results of the PHPP 2004 calculations for the Smith House:

- **Specific space heat demand:** 8 kWh per square meter per year (2.5 kBtu/ft.^{2}/yr.). In relationship to the treated floor area (TFA), this calculation describes the total amount of energy that the Smith House consumes for heating on an annual basis per square meter of TFA. (TFA is the discounted interior floor area—stairs are subtracted and storage and secondary spaces are only counted at 60% to determine the actual area that is livable.)
- **Whole-house specific primary energy demand:** 111 kWh/m^2/yr. (35.2 kBtu/ft.^{2}/yr.). The specific primary energy demand describes the total amount of source energy that the Smith House consumes for space conditioning, household electricity, domestic hot water, and miscellaneous mechanical electricity on an annual basis per square meter of TFA.
- **Peak heating load:** 13.1 W/m^2 (4.2 Btu/hr/ft.^{2}). The peak heating load describes the maximum energy input per square foot of TFA needed on the coldest day of the year to keep the house at 68°F. The mechanical system is sized on this value.
- **Airtightness:** 0.6 ACH_{50}. Air changes per hour at 50 pascal pressure.
- **Surface area-to-volume ratio (A/V):** 0.74. The A/V describes the compactness of a building. If a building is very compact, then the heat loss relative to the enclosed volume is minimized. For example: A home that has the dimensions of 10 m x 10 m x 10 m has a surface area of 600 square meters. The ratio is calculated by dividing 600 by 1,000 = 0.6. A ratio below 1 is recommended for Passive Houses in cold climates. In warmer climates, it is not as crucial to minimize heat loss by the compactness of the design.

Over the past six years of occupancy, the home's energy consumption has varied with weather patterns—but the average measured heating energy consumption has been within 10% of the modeled predictions. The overall whole-house specific primary energy demand is shown in the graph. It is significantly lower than predicted due to the owner's conservation practices. Klingenberg achieves even greater savings than anticipated with her use of high-performance appliances—beyond the assumed energy-efficient appliances specified in the modeling program.

Total Annual Source Energy Use



components is no less than 4°F from the temperature of the interior walls. But in the Smith House, and in Passive Houses generally, air mixes very slowly and evenly, keeping surface temperatures even, which helps to reduce stratification.

The fresh air intake for the ventilation system is a 100-foot-long, 8-inch-diameter PVC "earth tube" buried 6 feet underground, sloping away from the house to drain condensation. A filter at the intake keeps out mold, mildew, and other organic matter. The earth tube enters the house from under the slab, and so does not act as a thermal bridge. In the winter, the earth tube prewarms the incoming air to above-freezing temperatures; in the summer, it precools and dehumidifies the incoming air, keeping the house comfortable without any mechanical air conditioning.

Thick, insulated walls and high-quality windows are common features of Passive Houses.

Economics

Construction cost for the Smith House, using exterior dimensions, was $94 per square foot—at the time, 17.5% more than a conventionally constructed home—but with 10 times the energy performance. Simple payback for the Smith House would be about 17.5 years—the home's average utility bill is $50 and a house of comparable size in the same climate averages $150 per month, yielding a monthly savings of $100. But this distorts the picture, since simple payback does not consider interest or energy price increases. The initial project budget did not include the installation of a PV system or rainwater catchment and distribution system that would have made the home more self-sufficient. But preparations were made for adding these features in the future.

Access

Katrin Klingenberg (katrin@passivehouse.us) is the cofounder and executive director of the Passive House Institute US, which promotes the Passive House standard. She designs and consults on Passive House projects across North America, and is a licensed architect in Germany.

Mike Kernagis (mkernagis@passivehouse.us) is the cofounder and program director of the Passive House Institute US. He was one of the first builders to adopt and build to Passive House standards, including the nonprofit Ecological Construction Laboratory building.

RESOURCES

Whether you're a newcomer to renewable energy (RE) or an old hand, knowing who's who—and their respective acronyms—helps keep up with the latest industry news and developments.

by Doug Puffer, with Kelly Davidson

American Council for an Energy-Efficient Economy (ACEEE)

www.aceee.org

This nonprofit organization was founded in 1980 to help advance energy efficiency as a means of promoting economic prosperity, energy security, and environmental protection. Toward that end, ACEEE conducts in-depth technical and policy analyses, advises policy makers and program managers, convenes conferences and workshops, assists and encourages the media to cover energy-efficiency policy and technology issues, and educates businesses and consumers through reports, books, conference proceedings, media outreach, and their Web site.

American Council on Renewable Energy (ACORE)

www.acore.org

Founded in 2001, this membership-based, nonprofit organization engages stakeholders from private enterprise, academia, government, and financial institutions to expand RE markets and promote effective energy policy. From its offices in Washington, D.C., and San Francisco, the group organizes annual conferences and monthly webinars that address issues facing the scope of RE industries—wind, solar, geothermal, biomass and biofuel, hydro power, tidal/current energy, and waste energy.

American Solar Energy Society (ASES)

www.ases.org

As a leading advocacy group for solar energy, energy efficiency, and other sustainable technologies, ASES conducts extensive research and publishes reports on its findings that help shape policy and professional standards. Established in 1954, the nonprofit group has regional chapters in 40 states, with a national membership of more than 13,000, including energy professionals and grassroots supporters. ASES publishes *Solar Today* magazine, is the organizer of the annual National Solar Home Tour, and hosts the annual National Solar Conference.

American Wind Energy Association (AWEA)

www.awea.org

This trade organization represents more than 2,500 wind-industry stakeholders from the United States and around the world, including turbine and equipment manufacturers, project developers, consultants, utilities, and service providers. In addition to publishing a weekly newsletter on wind energy news and hosting its annual Windpower conference, AWEA works with Congress to ensure that wind-industry interests are addressed in RE legislation. AWEA provides communications and installation virtual "tool kits" for folks interested in home-scale wind energy. The group also tracks wind-energy statistics and collaborates on key policy papers and research reports.

Database of State Incentives for Renewables & Efficiency (DSIRE)

www.dsireusa.org

Established in 1995 and funded by the U.S. Department of Energy, DSIRE is an ongoing project of the North Carolina Solar Center and the Interstate Renewable Energy Council (IREC—see below). The Web site is *the* go-to source for information on state, local, utility, and federal incentives.

Electric Auto Association (EAA)

www.eaaev.org

Since 1967, this nonprofit group has provided a forum for electric vehicle (EV) enthusiasts to share ideas and experiment with EV technology. Through public exhibits of member-built EVs and other educational events, the group promotes EVs as practical, clean, and quiet alternatives to gasoline- and diesel-fueled vehicles. Based in San Jose, California, the group has regional chapters throughout the United States, two in Canada, and one in Europe.

Energy Star

www.energystar.gov

In 1992, the U.S. Environmental Protection Agency (EPA) introduced Energy Star as a voluntary labeling program to identify and promote energy-efficient products to reduce greenhouse gas emissions. Four years later, the EPA joined with the U.S. Department of Energy (DOE) to establish particular product categories. Partnered with more than 17,000 private and public sector organizations, the Energy Star label is on major appliances, office equipment, lighting, home electronics, and more. The EPA has also extended the label to cover new homes and commercial and industrial buildings.

Institute of Electrical and Electronics Engineers (IEEE)

www.ieee.org

Founded in 1884 by a small group of electrical professionals, IEEE is dedicated to fostering technological innovation and excellence. With more than 395,000 members in more than

160 countries, it has developed widely accepted standards and practices, many of which are integrated into the wide array of RE equipment in use today.

Interstate Renewable Energy Council (IREC)

www.irecusa.org

Formed in 1980, the IREC provides a national forum for technical and policy experts to collaborate on RE research, rules, and issues. The nonprofit, membership-based group has taken a leadership role in establishing uniform guidelines and standards for training programs, and for solar and RE professionals. Its members include state and local government agencies, national laboratories, and RE organizations.

National Renewable Energy Laboratory (NREL)

www.nrel.gov

As the principal research laboratory for the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy, NREL provides expert analysis that influences public policy and the nation's energy goals. The laboratory also performs research and testing that helps the public and private sectors bring RE solutions to market.

North American Board of Energy Practitioners (NABCEP)

www.nabcep.org

This nonprofit organization offers certification programs for professional PV and solar thermal installers, and is designing a parallel program for wind-energy practitioners. NABCEP's certifications are widely regarded as a measure of professionalism within the industry.

Office of Energy Efficiency and Renewable Energy (EERE)

www.eere.energy.gov

Part of the DOE, the EERE is charged with creating programs and policies to facilitate the deployment of energy efficiency and RE technologies.

Solar Energy Industries Association (SEIA)

www.seia.org

Established in 1974, this national trade group advocates for policy and legislation that reduce barriers and improve market conditions for the U.S. solar energy market. The Washington, D.C.-based group represents nearly 900 solar companies in the PV, solar water heating, concentrating solar power, and solar hybrid lighting industries.

Solar Electric Power Association (SEPA)

www.solarelectricpower.org

Formed in 1992 as the Utility Photovoltaic Group, SEPA is working to bridge the divide between electric utilities and solar companies. By providing research and tactical support for its 375 members, the group aims to alleviate the technical and market issues impeding the use and integration of solar-electric power by utilities.

Solar Rating and Certification Corporation (SRCC)

www.solar-rating.org

SRCC is an independent third-party organization that administers a certification, rating, and labeling program for solar collectors, and a similar program for complete solar water heating systems.

Underwriters Laboratories (UL)

www.ul.com

Established in 1894, UL is an independent product-certification company that evaluates products for compliance to designated safety standards. The company reviews more than 19,000 types of products, components, materials, and systems annually—including wind-energy and PV production equipment.

U.S. Environmental Protection Agency (EPA)

www.epa.gov

Established by President Richard Nixon through an executive order to Congress, the EPA is responsible for enforcing the environmental policy and standards of the U.S. government. In addition to monitoring oil pollution, chemical use, air quality, and drinking water standards, the EPA oversees the fuel economy of automobiles sold in the United States and administers the Energy Star program, a voluntary program that certifies the energy efficiency of appliances and buildings (see Energy Star listing).

U.S. Department of Energy (DOE)

www.energy.gov

Formed by President Jimmy Carter after the 1977 oil crisis, the DOE administers initiatives aimed at ensuring optimal use of fossil fuels, modernizing energy infrastructure, and advancing the use of sustainable energy sources. In addition to jointly managing the Energy Star program with the EPA, the DOE also oversees the environmental cleanup of the national nuclear weapons complex and the handling of nuclear material.

U.S. Green Building Council (USGBC)

www.usgbc.org

The USGBC is an authority on green-building practices, as well as an active voice in the development of green-building legislation and guidelines. The nonprofit, membership-based group is best known for its Leadership in Energy and Environmental Design (LEED) green-building certification program—a voluntary system that certifies residential and commercial buildings to a certain level, based on their use of sustainable measures, such as energy-efficient and water-saving technologies. Additionally, the USGBC administers a highly respected credential program for green-building professionals.

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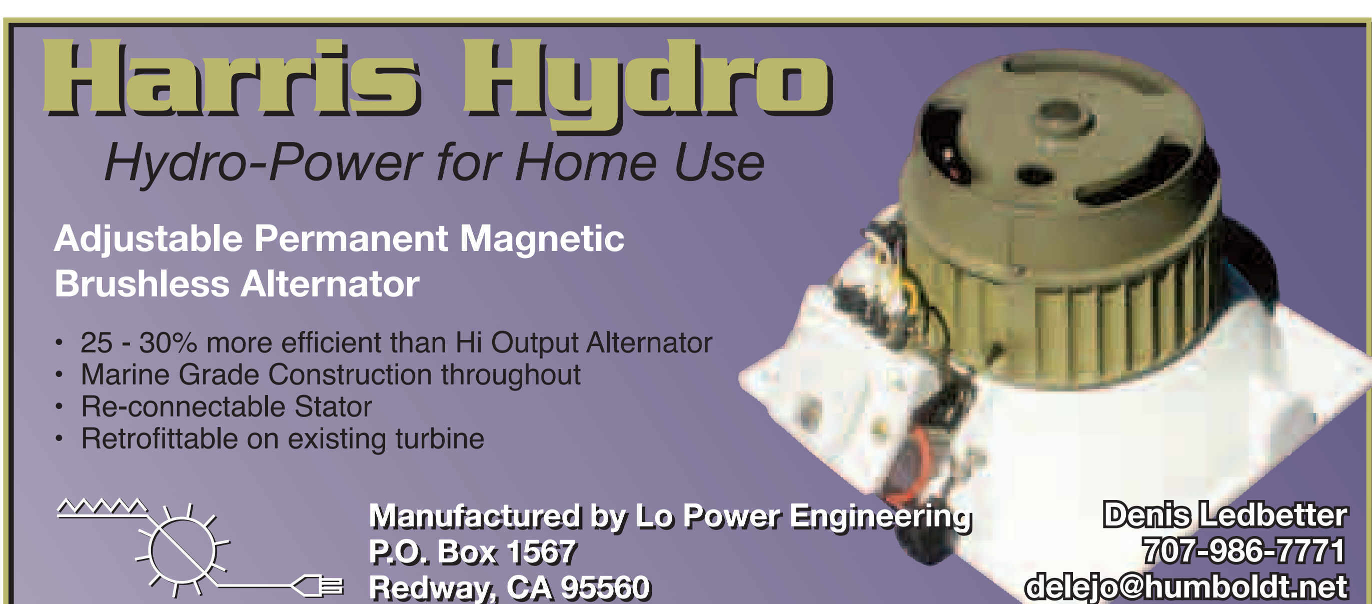

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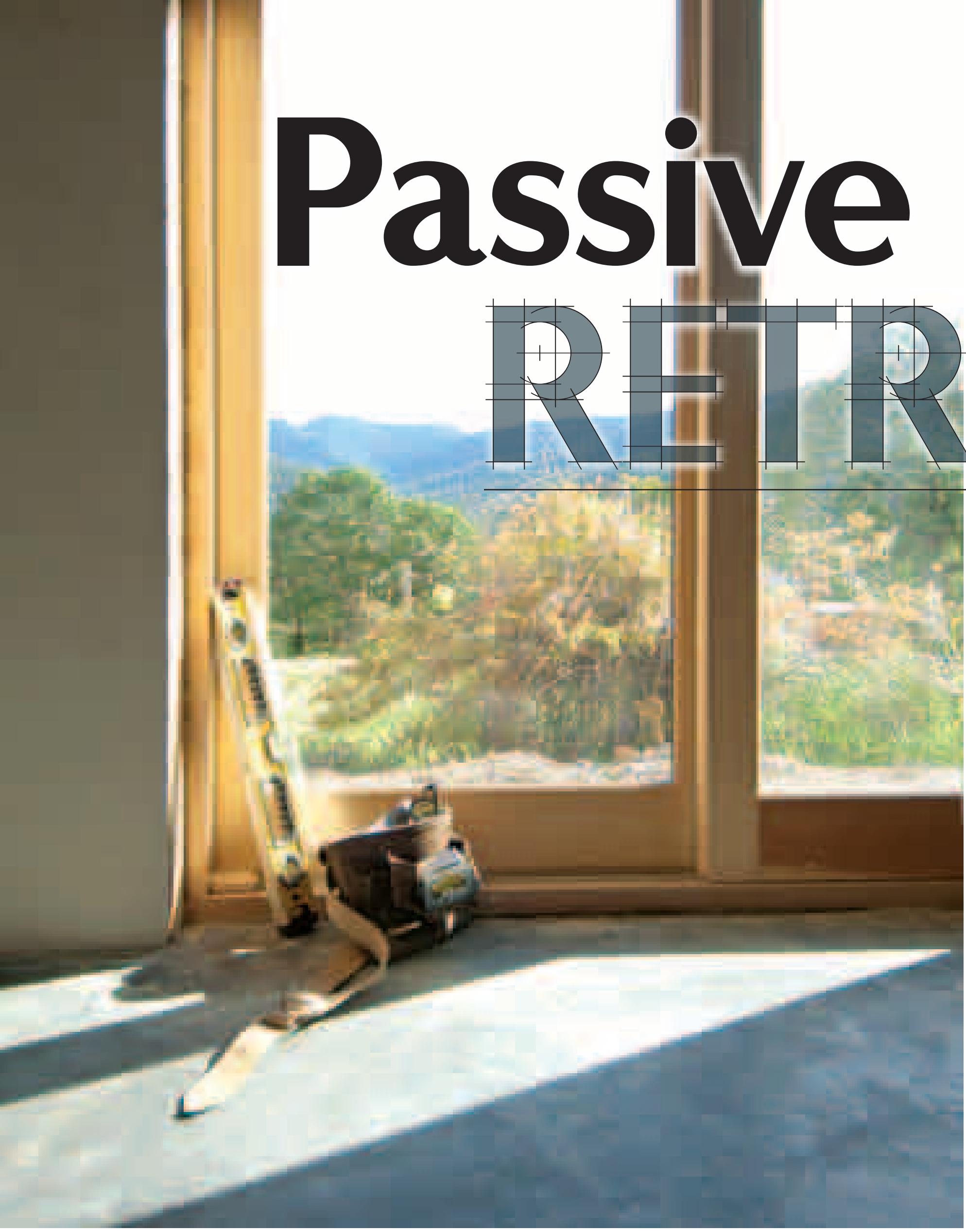
Passive Solar RETROFIT

by Dan Chiras



Shawn Schreiner

Passive solar design is a great strategy for those who want to build a new home that heats and cools itself naturally—without costly mechanical equipment and fossil fuels. But some passive solar techniques can also be incorporated into existing buildings.

This article will help you benefit from this clean, low-tech, cost-effective, and environmentally friendly form of space heating. We will explore ways to open up the south-facing facades to permit the low-angled winter sun to enter, as well as ideas on building passive solar additions and attached sunspaces.

OPTION 1: Opening Your Home to the Sun

Retrofitting an existing home or business for passive solar requires that the building have room for windows in a south-facing wall with unfettered access to the sun, all winter long. No trees or buildings should shade the wall during daylight hours, and solar access should be available from at least 9 a.m. until 4 p.m.

Newly built passive solar homes are typically rectangular buildings with the long axis running from east to west, for maximum south-facing windows—to get the best solar gain. In a passive solar retrofit, the south-facing wall doesn't need to run the length of the home or business, although that's ideal. Any south-facing wall will work, although the more windows, the better. In passive solar homes, the amount of south-facing glass varies by climate and solar heating goals. Typically, passive solar designers aim for a south-facing glass area between 7 and 18% of the square footage of a building with traditional 8- to 9-foot ceilings. The colder the climate and the more solar heat needed, the higher the percentage.

Install Energy-Efficient Windows

After you have weatherized your building (see "First Things First"), it's time to install windows on the sunny south side of the building to increase direct solar gain. In most retrofits, there will only be room for a couple of windows, so your space is unlikely to experience overheating.

Simple as it sounds, adding openings in a home can be tricky. It will, for instance, require some framing to create a rough opening into which the window will be installed. As a result, it is a job generally best left to professional builders—or, better yet, to professional window installers.

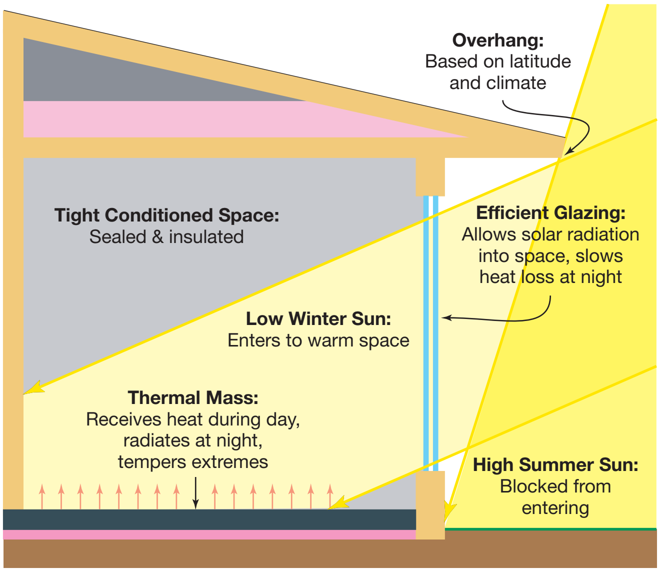
Shawn Schreiner

Windows should be high-quality and installed with appropriate flashing to prevent air and water infiltration.

To add a window, an installer will cut a large hole in the wall through the interior drywall and exterior sheathing and siding. The installer then removes the wood framing in the wall and installs headers—horizontal load-bearing framing over the top of the opening. The header supports the weight of the wall above it and transfers that weight to the framing members installed along the sides of the windows. This arrangement transfers the load from the roof through the headers and framing members, instead of to the window, which would break under the weight.

After an opening has been framed, it is time to install the new window. Be sure to follow directions very carefully. Windows must be sized about a half an inch smaller than the rough opening.

PASSIVE SOLAR BASICS



FIRST THINGS FIRST

Seal the Leaks

Passive solar retrofitting begins not by adding windows, though this is an important measure, but by weatherizing and insulating. This is critical to efficiently heating any home, solar or not. Be sure to conduct an energy audit or hire a professional auditor to do the job. An energy auditor will inspect your home and perform a blower-door test, which tells how leaky a building is and identifies all cracks and crevices in a building envelope. The leaks need to be sealed to make the building closer to airtight.

Leaks in the building envelope can be sealed with caulk or foam. Those around doors and windows are typically sealed with weather-stripping. Once again, you can do the work yourself or hire a professional energy retrofitter. Well-trained professional energy retrofitters will very likely do a better job—and they'll get it done fast.

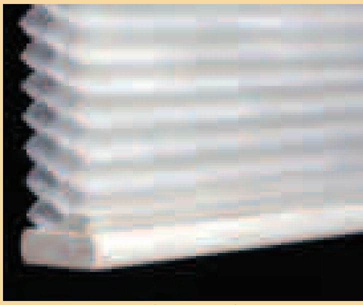
Insulate!

Ben Root

After you've sealed the leaks in the building envelope, it may be time to improve your home's insulation, depending on what the energy audit revealed. Be sure to insulate the walls, ceilings, and the foundation. Based on new DOE recommendations and rising fuel costs for heating and cooling, ceiling insulation should be boosted to R-50 or R-60, if possible. Wall insulation should be increased to R-30, although that's not often possible in existing homes or businesses—there's just not enough space with 2-by-4 construction. Insulation under floors over unconditioned space (i.e., crawl spaces) should be boosted to R-25 in most climates. Remember, insulation is just as important in a hot climate as it is in a cold climate. Don't skimp on insulation just because you live in Arizona. Cooling costs in hotter climates can be greater than heating bills in cold northern climates.

Install insulated window shades over all windows to hold heat in at night—and don't forget to use them! Insulated window shades come in several varieties. Cellular shades, which look like honeycombs, are an excellent choice and are widely available online and through numerous stores—even many building supply stores carry them. Warm Window shades, which consist of a layer of heat-reflecting metalized polyester film sandwiched between layers of polyester, also are effective. You can purchase the materials and sew them yourself, or hire a sewing expert to make the curtains for you.

Sealing a home or business, then adding insulation, can reduce heating (and cooling) costs dramatically—by 10 to 50%, depending on how leaky and underinsulated your home or business is. These measures help retain the hard-gained solar heat you're about to invite into the building with your passive solar retrofit.



Courtesy Dan Chiras

Courtesy Dan Chiras

Don't let the rustic style fool you—this home's well-designed overhangs shade the south-facing windows from the high summer sun.

Window frames attach to the rough opening. The window must be leveled, then attached on the sheathing on the outside by nailing its bottom metal or plastic flange. Then the window is squared and nailed the rest of the way around. Any gaps between the window and the wooden framing members are filled from the inside with foam insulation such as backer rod or foam tape, or expanding spray foam insulation designed specifically for window and door installation. Using spray foam that expands too much—like a product designed to seal large gaps and cracks—can damage the window and void the window manufacturer's warranty, so read instructions carefully.

After the window is secured, be sure to apply adhesive sill flashing, a tape-like product that seals the window opening from the outside to prevent air and moisture from penetrating. Once the window is in place, install the trim and caulk around it to provide an additional airtight seal.

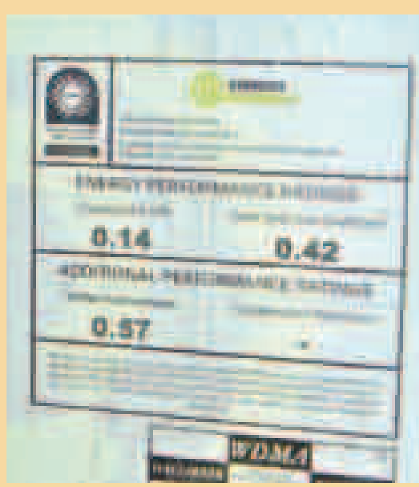
A WORD ON WINDOW CHOICES

For starters, determine the type of window you can use in the space. The most airtight (and therefore, most efficient) windows on the market are inoperable windows—that is, they can't be opened. They are ideal for passive solar gain, and should be used if there are enough other operable windows in the building.

If you install operable windows, consider purchasing hinged windows—casement, hopper, and awning windows. These windows open with the aid of a crank mechanism and shut very tightly against weatherstripping—provided they are well-made. Slider windows—single-hung, double-hung, and horizontal sliders—tend to be less airtight and aren't generally advised for passive solar applications, unless you buy high-quality units.

For optimum performance, new windows should be as energy-efficient as possible. Look for low-emissivity (low-e) double-pane windows. These windows have a special transparent, heat-reflective coating to prevent heat from escaping in the winter and entering in the summer.

Windows used for passive solar gain should also have a high solar heat gain coefficient (SHGC). A rating from 0 to 1, SHGC indicates the amount of solar energy that passes through a window. The higher the number, the more solar heat the window allows to enter. If you are in a cold climate, buy windows with SHGC of 0.5 or higher. In slightly warmer climates, windows from 0.4 to 0.5 SHGC will work.



Courtesy www.seriousmaterials.com

Not all windows are alike—check the sticker for important performance ratings.

Most low-e coatings reduce solar heat gain coefficient considerably. However, a couple of window manufacturers have devised low-e coatings that don't interfere with solar heat gain. One option is PPG Industries, which manufactures two low-e/high SHGC products: Sungate 500 and Sungate 100 window glass with SHGC of about 0.7. This glass is excellent in colder climates—where lots of solar gain is desired. However, PPG only manufactures window glass—not the framing unit. To obtain windows with their glass, you will need to contact a local window manufacturer to see if they will order PPG Sungate glass and install it in their frames. Another U.S.-based option is Serious Windows, which sell a "high" SHGC window, with values ranging from 0.39 to 0.5. Several Canadian companies—Thermotech, Accurate Dorwin, and Inline, for example—manufacture low-e windows with coatings that allow several different solar heat gain coefficients.

For best performance, south-facing windows should be argon-filled, have a condensation resistance of 0.5 or higher, visual transmittance of 0.5 or higher, and a U-factor of 0.3 or lower, (the lower, the better). Argon insulates glass. Visual transmittance is a measure of visible light entering the window (below 0.5 and the window appears dark). U-factor is a measure of heat movement through a window. It's the reciprocal of R-value, so a window with an R-value of 3 has a U-factor of 0.33. Air leakages should be under 0.3, preferably about 0.1 cubic feet per minute per square foot. Since you will be dealing directly with the window manufacturer, if you insert Sungate window panes, be sure to stipulate these parameters.

South-facing windows live a difficult life. They are exposed to lots of sunlight, and choosing frame materials that resist expansion and contraction is smart. Wood-framed windows with an exterior cladding of aluminum to protect against the weather are generally good performers, as well as all-fiberglass units. Avoid aluminum-framed windows unless the manufacturer has insulated the frame, since uninsulated metal frames conduct heat out of the building in the winter and into the building during the summer. Buy windows with warm edge spacers, which consist of foam inserted between the panes of glass along the perimeter of the window. They reduce heat loss around the perimeter of a window, greatly decreasing heat loss in the winter and heat gain in the summer. Warm edge-spacers also reduce condensation, which damages wood sills and sashes (the wood that holds the panes of glass in place).

Shawn Schreiner

Adding thermal mass may be one of the most difficult tasks in a passive solar retrofit.

Shade Windows

For best results in a passive solar retrofit, new south-facing windows should be shaded by eaves to prevent summertime overheating. You may need to construct eaves or install retractable awnings over these windows if there is no overhang on the south side of the building.

Add Mass

If you dramatically increase the amount of south-facing glass, you may need to add thermal mass inside. Thermal mass is any material that absorbs solar energy during the day and releases it at night or on cold days, preventing overheating and helping to maintain a more constant internal temperature. Thermal mass materials include concrete, brick, stone, and tile.

As a general rule, no additional thermal mass is required if the south-facing glass is less than 7% of the sunlit floor area. Incidental mass—that is, mass in the building such as drywall and framing materials—is sufficient to accommodate the solar gain. If south-facing glass exceeds the 7% mark, additional thermal mass is required. Generally, for each square foot of south-facing glass over the 7% limit, you need to add 5.5 square feet of 4-inch-thick floor mass—that is, mass that sunlight will strike. For walls used as thermal mass, you need 8.3 square feet of 4-inch-thick thermal mass in walls. Floor mass not struck directly by sunlight is virtually useless.

Adding 4 inches of thermal mass to walls and floors is difficult. In most buildings, smaller amounts are added by installing tile on the floor, or adding a second layer of drywall or a brick facing to sun-bathed walls. All three strategies add thermal mass and help prevent overheating when solar glazing exceeds the 7% mark.

Mass should be dark to increase absorption of sunlight, but not too dark. Clay-colored tile, for instance, is a good compromise for aesthetics and performance. If the mass is too dark, it can create hot spots in your home.

OPTION 2: Solar Addition

If you are planning on adding a new room, consider building it on the south side of the building and designing it for passive solar gain. A solar addition may be heated almost entirely by sunlight and could provide some heat to adjoining spaces, if done correctly. Solar additions are typically designed as direct gain structures—rooms with south-facing windows that allow the sun's rays to enter, directly heating the space.

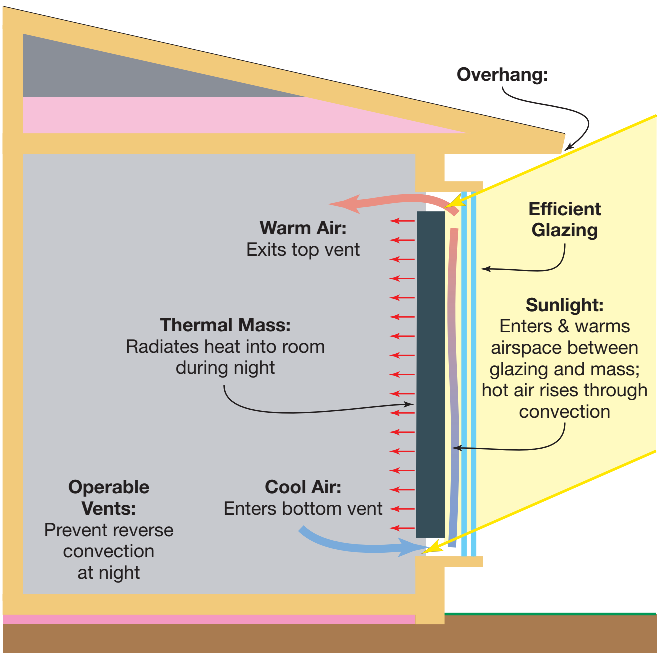
Another passive solar option is a Trombe or thermal storage wall. This design incorporates a massive wall behind windows on a south-facing exterior wall. Sunlight streams through the windows, heating up the wall. Heat then migrates by conduction through the wall to the interior, radiating to the space at night. Windows installed in the mass wall allow daylight and some direct solar gain. Vents in the upper and lower reaches of the wall allow room air to circulate between the mass wall and the glass where it is warmed. Cool room air enters at the bottom vents and is warmed in the airspace between the glass and mass wall, then exits through the top vents, providing additional daytime heat.

Thermal storage walls work well in all climates, though they need to be properly designed and built. The glass is typically a low-e double-pane glass with a high SHGC. (Non-low-e or uncoated window glass can also be used in such applications. Uncoated glass has a higher SHGC coefficient than ordinary low-e glass.) That glass is typically placed 3 to 6 inches from the mass wall.

This ground-floor bump-out addition gains floor space while moving south glazing from under the porch overhang.

Courtesy Dan Chiras

TROMBE WALL FUNCTION



Thermal storage walls can be made from a number of types of thermal mass, poured concrete, cement blocks filled with sand or concrete, brick, adobe, or rammed earth. Walls are typically 8 to 18 inches thick, depending on the material.

Vents need to be sized to ensure adequate airflow. As a rule, you'll need 2 square feet of vent, divided equally between the top and bottom of the wall, for every 100 square feet of thermal storage wall. Closable vents are vital to prevent warm air from flowing through the airspace at night, losing the heat to the outside. Automatic louvers are more convenient than manually closed vents.

Designing and sizing a Trombe wall requires knowledge and experience. Be sure to consult books on passive solar design or consult with an experienced architect to determine wall thickness, type of material, size of vents and vent closures, spacing between the glass and the mass wall, and other parameters. Be sure not to cover the interior surface of the Trombe wall. Many homeowners make the mistake of furring out the wall, then applying drywall, which effectively insulates the interior surface of the wall, dramatically reducing heat radiation. A coat of paint or plaster makes an effective and attractive finish.

OPTION 3: Attached Sunspaces

Many people like the idea of all-glass sunspaces attached to their home. They are attractive, fairly inexpensive, and available in kits. They're often touted as three- or four-season rooms. Unfortunately, since they lack insulation, all-glass attached sunspaces tend to undergo wide temperature swings, overheating in sunny weather and then cooling off to brisk temperatures during cloudy weather or at night. Direct sunlight's UV radiation is tough on furniture and carpets, and the brightness can also be hard on the eyes, since there's nothing to temper the glare.

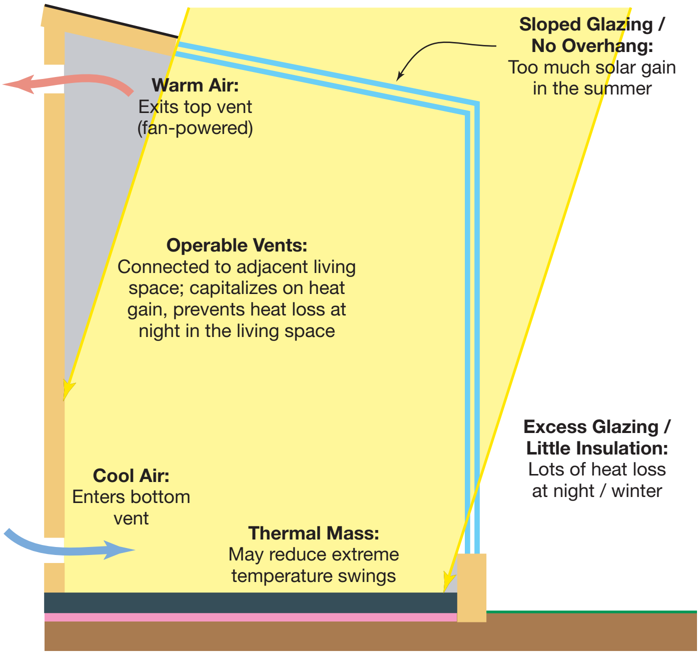
Despite the drawbacks, sunspaces can be used as a giant solar collector to heat adjacent rooms in your home. Installing a quiet, energy-efficient, thermostatically controlled fan in the wall of the sunspace will move the solar-heated air into adjoining rooms. Warmed air can also be ducted to back rooms. (For maximum efficiency, seal and insulate the ducts, and keep duct runs as short as possible.)

At night, close off the sunspace from the main living area to thermally isolate it from the rest of the home. This prevents heat from the house from moving into the sunspace and then to the outside—where it does you no good. You should also consider installing insulated shades to reduce heat loss at night, especially in those attached sunspaces that will serve as additional living space.

Let the Sun Shine In!

Adding solar windows, a solar addition, or an attached sunspace can increase your use of solar energy, a clean, abundant, economical, and renewable energy resource. All three will perform well, if properly designed and constructed. You need to choose which of the options fit your situation.

SUNSPACE PROs & CONs



Courtesy Dan Chiras

This sunspace built on the south side of the home may seem like a good idea, but without the removable shading could suffer from overheating in the summer.

If south-facing walls in your home offer some room for additional windows, this might be the best option. Direct gain is a great way to heat. If you are planning on adding on to your home, a solar addition on the south side of your home will work well. A thermal storage wall may be ideal for rooms like offices in which you want the solar heat, but don't want all the extra sunlight. If there's room for an attached sunspace, and you can deal with their limitations, that may be a good way to go. Or, you can design the attached sunspace to serve as a large solar collector, optimized to heat neighboring rooms. All options can cut your heating costs and very likely add to the value of your home.

Access

Dan Chiras (danchiras@evergreeninstitute.org) writes about green building and renewable energy, and directs The Evergreen Institute, where he teaches workshops and provides instructor training on passive solar heating and cooling, solar electricity, wind energy, energy efficiency, and green building.

Further Reading:

"Sun-Wise Design: Avoiding Passive Solar Design Blunders" by Dan Chiras, *HP105*

Green Home Improvement by Dan Chiras (RS Means, 2008)

The Solar House by Dan Chiras (Chelsea Green, 2002)

code corner

Common Questions about Grid-Tied Systems

by John Wiles

In the course of helping the PV industry with *NEC* issues and questions, I get some that are repeated many times. There are always a few that need clarification or repeating.

Inverter DC Grounding-Electrode Conductor

In *HP133*, 690.47(C) in both the 2005 and 2008 editions of the *NEC* was discussed. Since this section is permissive in both codes, either the 2008 or 2005 requirements may be applied in jurisdictions using either edition. Everyone using the *NEC* should at least read Article 90 Introduction—where in Section 90.5 it is explained that the *NEC* has permissive (optional) requirements and mandatory requirements. Sections 690.47(C) in both editions are based on requirements found in Article 250, which is unchanged. For 690.47(C), then, these permissive requirements can be applied in jurisdictions using either edition. As always, the inspector has the final say.

It should be clarified that the combined conductor permitted by 690.47(C)(3) in the 2008 *NEC* originates at the inverter and runs to the first grounding bar in a panel where a grounding electrode conductor is attached. It should be noted that *this* combined DC inverter grounding-electrode conductor/AC inverter equipment-grounding conductor does not originate at the PV array. The PV array is normally grounded with an equipment-grounding conductor routed with the DC circuit conductors, per 690.43. Additional grounding of the PV array may be required by 690.47(D) when the array is ground- or pole-mounted, or mounted on a separate structure from the inverter.

Main AC Service Disconnect Ground-Fault Protection

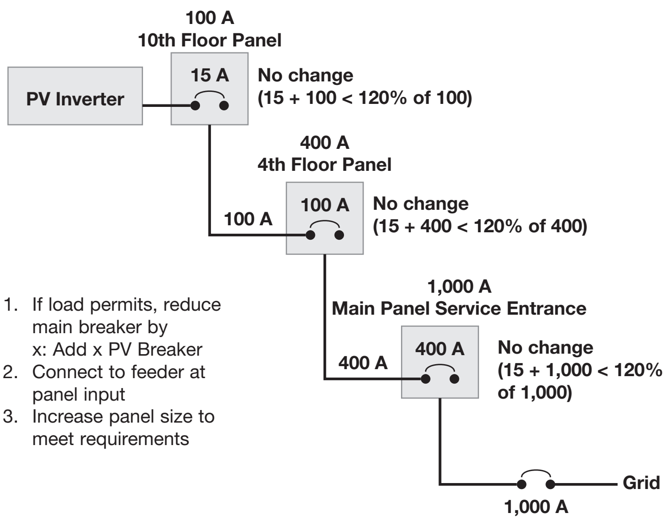
NEC Section 230.95 requires that solidly grounded wye services be provided with ground-fault protection for services rated at 1,000 amps or more, with a line-to-ground voltage

With increasing numbers of PV installations, the same questions about how to meet specific *NEC* requirements often arise.

John Wiles

Commercial Utility-Interactive Systems

690.64(B)(2)
PV + Main ≤ Panel



After applying 690.64(B)(2) to all panels and feeders, it may be cheaper and easier to add a second service to the building.

of more than 150 volts, but not exceeding 600 volts phase-to-phase. This protection is generally provided by a main disconnect, consisting of a circuit breaker with an attached or included ground-fault protection device (GFPD). How should the PV designer, installer, or inspector proceed where a utility-interactive PV system connection could backfeed this GFPD breaker? The answer: With a great deal of caution.

First, Underwriters Laboratory (UL) standards state that if a circuit breaker is *not* marked "line" and "load," it has been evaluated for current/power flow in both directions—and is suitable for backfeeding—which is the case with most new, smaller, molded-case circuit breakers. However, retrofit situations may have main disconnect circuit breakers that are 40 or 50 years old—these may have "line" and "load" markings, indicating that the breaker should *not* be backfed.

Let's assume that we have a main disconnect breaker that is suitable for backfeeding and is also equipped with a GFPD as required by the 2008 *NEC* and earlier editions. Discussions with engineers at UL and with circuit breaker manufacturers reveal that the GFPD may not have been tested for backfeeding in a method that duplicates the utility-interactive PV situation. When a ground-fault trips a GFPD breaker that is being backfed by a PV inverter, both the line and load terminals may be energized at the same time for up to 2 seconds as the inverter shuts down. Many older GFPD devices could be damaged when this happens. Some of the newer GFPD breakers are not susceptible to this kind of damage, but no one seems to have a universal answer that covers all GFPD breakers in all installations. So, the first hurdle is to get the design engineer at the breaker/GFPD manufacturer to provide written statements that the GFPD device will not be damaged when tripped while being backfed by a utility-interactive inverter.

The second hurdle is posed by meeting the exception to 690.64(B)(3). How are the load circuits protected from ground-fault currents from the inverter? An analysis of the various impedances involved (inverter-output-source circuits vs. utility-source circuits) to determine how currents would be shared between the inverter and the utility would not be simple. It may be possible that the inverter can source sufficient fault currents so that the GFPD does not trip. Also, the GFPD has adjustable trip points and the *NEC* provides no guidance on how they should be set in either a non-PV or a PV installation. When the adjustment ranges over several hundred amps on a 1,000 amp GFPD breaker, it is not clear how this adjustment should be made. If a GFPD is put on the output of the inverter, there is the question of how it should be connected and whether it would provide the desired protection.

My opinion is that when the existing installation has a main breaker or any breaker (or any fused disconnect) with a GFPD function, then that device should not have a utility-interactive inverter attached to any circuits that feed the load terminals of the GFPD. Supply-side connections (690.64(A)) are the way to make these PV installations and avoid these problems until they are resolved by a combination of changes to the *NEC* and the UL Standard, and a better understanding of the situation by PV installers, electricians, and the electrical inspectors.

690.64(B) All The Way

Code Corner 134 dealt with load-side connections. However, the proposed changes for the 2011 *NEC* were rejected, so *NEC* 690.64(B) and 705.12(D) will be in force for awhile. These code requirements apply to any bus bar or conductor that has multiple sources of supply (utility and PV inverter outputs) with each supply protected by an overcurrent device (fuse or circuit breaker).

In a typical utility-interactive PV system, the requirement would apply to all bus bars and conductors from the service disconnect (breaker or fused disconnect) to the first dedicated overcurrent device/disconnect on the inverter output circuit. Although the number of subpanels and conductors between the service disconnect and the PV

A modern breaker marked as suitable for backfeeding. Should it be used with a PV system connected to the load terminals or not? Exercise extreme caution!

inverter output may be numerous, and the load on the building large compared with the rating of the PV system, there is always the possibility that any conductor in this path may be subjected to backfed currents from the PV system. Each of those panel bus bars, and the conductors between them, must be sized to meet the requirements of 690.64(B)/705.12(D)—see the diagram above.

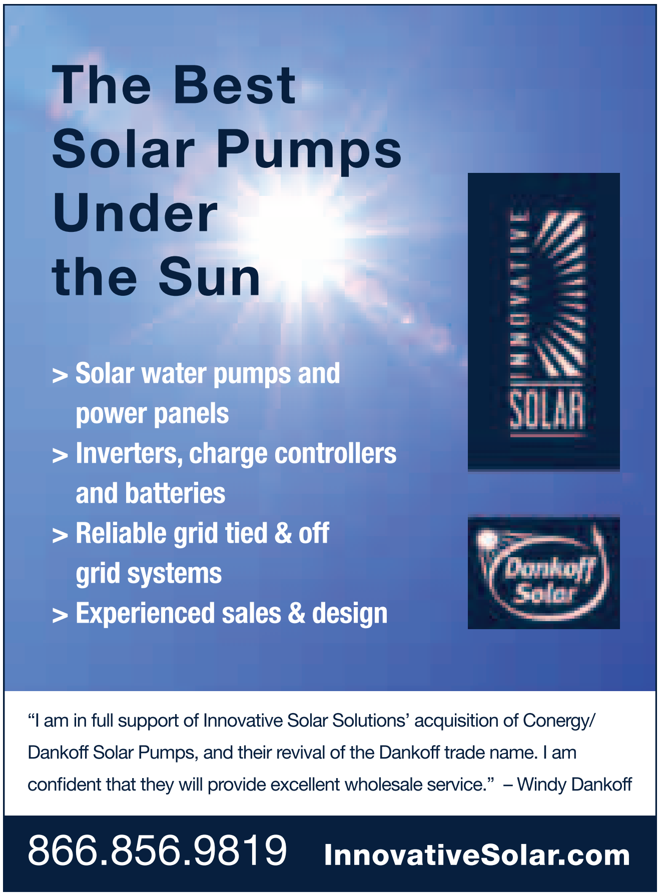
If the PV inverter output connection cannot be made at the very last breaker position in the most distant panel from the service disconnect, as required by 690.64(B)(7), then the calculations for ampacity and bus bars must be based on 100% of the total of all overcurrent devices supplying the bus bar or conductor. Without this opposite breaker configuration, it may be possible to overload portions of the bus bar or some conductors with current from both the utility and the PV system. The 120% allowance in *NEC 2008* 690.64(B)(2) cannot be applied, nor can just that first dedicated breaker connected to the PV inverter output be used in the calculations for each conductor and bus bar. Each panel bus bar and conductor segment must be examined to determine which breakers are limiting current to that specific bus bar or conductor. These are usually the main breaker on the panel and the single backfed breaker *in that particular* panel that is handling backfed current from the possibly distant PV inverter—not the dedicated breaker connected directly to the inverter. The 120% allowance has been lost that was allowed when the breakers were positioned at the bottom of the panels, and frequently the ratings of a main breaker and the panel are the same. Therefore it is not possible to have a breaker carrying backfed PV currents connected to this panel or conductor.

In some cases, the main breaker for a panel may be sized below the rating of the bus bar; this can allow a backfed breaker to be connected anywhere on that panel. Load calculations determine if the main breaker size can be reduced. If so, the sum of the rating of the main breaker (supplying utility power) and the rating of the backfed breaker in that panel may not exceed 100% of the bus bar rating for that panel. Plus, upstream panels and circuits toward the service entrance must be analyzed to see if the 100% rule can be met. In many cases, a supply-side connection is the only option available.

Access

John Wiles (jwiles@nmsu.edu; 575-646-6105) works at the Institute for Energy and the Environment (IEE) at New Mexico State University. John provides engineering support to the PV industry and a focal point for PV system code issues.

Southwest Technology Development Institute • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html • PV systems inspector/installer checklist, previous "Perspectives on PV" and *Code Corner* articles, and *Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices*, by John Wiles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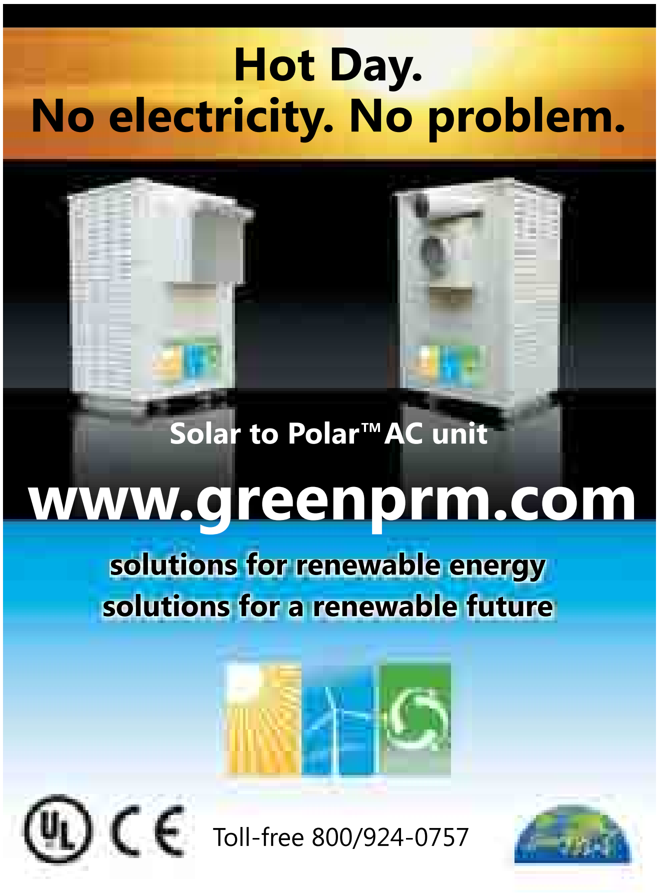
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What a Crock

by Kathleen Jarschke-Schultze

A big part of my and my husband Bob-O's off-grid life is working toward sustainability. For instance, we try to reduce our reliance on nonrenewable energy sources, like propane, whenever possible. My clothes dryer uses propane; so does my cook stove. In the sunny months, though, I use my solar- and wind-powered clothes dryer, an umbrella type that's parked out on the deck. I also use my solar oven for cooking. So when I was presented with a method of food preservation that uses no propane or electricity, I was enthusiastic, to say the least.

Live Salad

Our garden is large, so we eat our food fresh in season. We like to say, "This salad is so fresh, it doesn't even know it's dead yet." We harvest and store enough onions and potatoes to go from one season to the next. Canning tomatoes, chipotles, honey ketchup, pickles, and pickled beets are yearly events. Although I can grow really great cabbages, their storage has always eluded me.

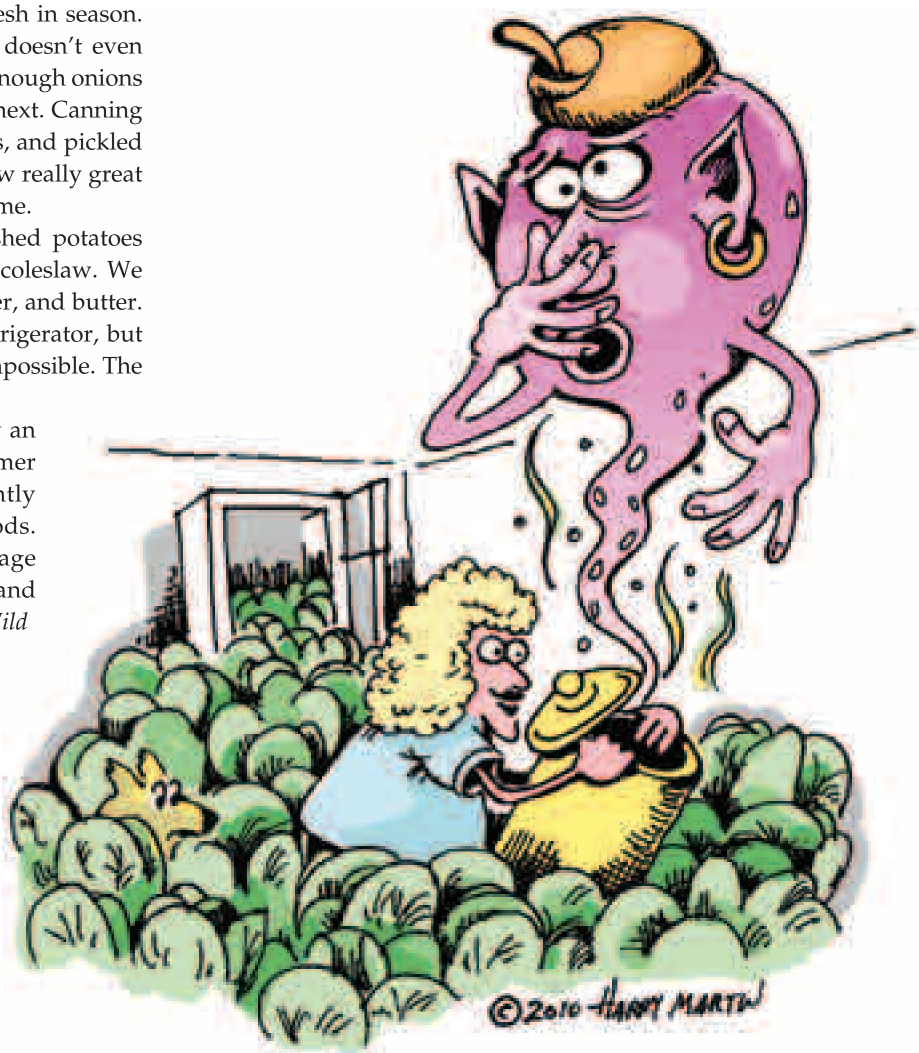
We love cabbage, colcannon (hot mashed potatoes and cabbage shreds mixed together), and coleslaw. We even like cabbage steamed with salt, pepper, and butter. Cabbage will last a very long time in a refrigerator, but fitting my whole harvest in our fridge is impossible. The answer for me turned out to be sauerkraut.

A couple of months ago, I dropped by an old neighbor's office to chat (he was a former neighbor; he's not old). He had recently become enamored with fermented foods. He shared some homemade red cabbage sauerkraut with me from his lunch box, and also shared Sandor Ellix Katz's book, *Wild Fermentation*.

Friendly Fermentation

We all eat fermented foods, probably every day. Every social culture has its fermented specialties. Some are eaten as live-culture foods, while others have their fermentation stopped by their continued processing. Live-culture foods are sauerkraut (or any vegetable crocked with brine), yogurt, cheese, miso, kimchi, tempeh, kefir, and vinegar. Fermented foods that are homogenized, cooked, or canned lose their "aliveness," as do breads, beer, wine, and sourdough.

After reading *Wild Fermentation*, I was primed for experimentation. For my birthday this year, as in years past, my dad sent me some money. I always make sure I spend it on something I've been wanting and haven't gotten around to buying yet. This year, it was a 5-liter Harsch fermentation crock. The hand-thrown earthenware crock includes a ceramic lid that fits perfectly into a special cast



gutter in the rim. When filled with water, the rim creates a seamless airlock with the lid. Gases generated from the fermentation process can escape because of their pressure, but air cannot enter. Two half-disc, unglazed stone weights came with the crock. These weigh down the vegetables or kraut so they are submerged in the proper depth of brine, $1^1/_2$ inches. If you've ever used a cloth-covered plate as a weight in a pickling crock, you'll understand how handy the weights are.

Just add salt: Even food preservation (in this case, food fermentation) can be a part of an energy-efficient homestead.

The first thing I did was start a batch of sauerkraut. It takes four to six weeks to ferment the kraut enough to eat. All you need is fresh cabbage, salt, and water. One Christmas, Bob-O gave me a mandoline, a manual food processor for precisely slicing firm fruits and veggies. It's like running your food through a knife instead of running a knife through your food. My mandoline has a support leg that swings out for maximum stability. The mandoline's razor-sharp blade can be adjusted, making it the perfect tool for slicing the cabbage for kraut-making. Because of the sharp blades, extreme caution is advised when using a mandoline. Most models come with a vegetable pusher/guard to protect your hand. Professional chefs often use a chain-mail glove for pinkie protection.

After slicing up my cabbage, I weighed out the green pile and the salt required, using $^1/_4$ ounce of plain salt per 2 $^1/_2$ pounds of cabbage. (Hint: It's easier to weigh whole cabbage heads than shreds.)

I placed a layer of shredded cabbage in the bottom of the crock and sprinkled the top with salt. Using my clean fist, I tamped down the cabbage. When the juices were released, I repeated the process until all the cabbage and salt were used up. My hand-pressed brine did not cover the cabbage adequately, so I made a brine of $^3/_4$ teaspoon of salt per quart of water to add.

I used the weighting stones to submerge the cabbage under the brine. I put the lid on the crock and filled the water channel with tap water. The crock then needed to be left at room temperature (68–72°F) for two to three days to get the fermentation started. I put mine on the dining room table so it would be positioned behind me as I work at my desk. The day after I crocked my first cabbage, a mysterious pinging noise, just like one of the sounds computers or other electronic devices emit for a variety of reasons, started. I searched for the cell phone, PDA, iTouch, or laptop that was alerting me to something, although I knew not what. I searched high and low several times until I happened to be standing near my newly filled crock when bubbles emerged from under the lid rim and through the water with a wet pinging sound.

Once the fermentation started, I wasn't supposed to open the lid for two weeks. Of course, I couldn't wait that long—I'm the kind of person who digs up a pea or two from the garden to make sure they are sprouting. So I looked inside. The cabbage's appearance was the same, but the open crock released the smell of fermentation, not strong or unpleasant, but sharp, a bit yeasty, and sour. After two days, I moved the crock to the cooler basement (40–60°F) to finish its fermentation and for storage.

Although I had to wait before tasting my kraut, I opened the crock about once a week to check on it. The kraut smell became very pronounced. It was hard to wait to sample some. I told a friend about my kraut adventure and he said he could remember raiding his grandmother's kraut crock before the fermentation was complete. (If you like sauerkraut, then you *really* like it.) When my kraut matured, I was able to give my 93-year-old dad a jar of homemade live-culture sauerkraut for his birthday.

The fermentation genie is out of the crock. I'm planting a variety of cabbages this year, along with lots of green beans, Romanesco cauliflower, and cucumbers. Carrot kimchi is calling to me. And food preservation—with only human energy used—is furthering our goal of sustainability.

Access

Kathleen Jarschke-Schultze (kathleen.jarschke-schultze@homepower.com) is enjoying her garden largesse at her off-grid home in northernmost California, and blogging at www.theoffgridlife.com.

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Inside a Battery

You may use them every day, but do you know what makes them work?

Batteries are energy storage devices that use electrochemical reactions to make direct-current electricity.

You may already be familiar with common types, such as alkaline batteries used in consumer devices; lithium-ion and nickel-metal hydride technology in cordless tools; and deep-cycle flooded lead-acid batteries for energy storage in renewable energy applications. The difference between them lies in their chemistries—different combinations of chemicals lend themselves to certain applications. Non-rechargeable alkaline batteries have been the low-cost solution for many portable needs. Lithium-ion batteries offer a powerful lightweight solution for rechargeable appliances like cordless tools. Deep-cycle lead-acid batteries deliver electricity over a long period of time. But what's behind a battery's energy-producing capabilities?

A battery cell has three main components: the anode, the cathode, and the electrolyte. The anode loses electrons and the cathode accepts electrons. The electrolyte is a solution that allows charged ions to move between the anode and cathode. Batteries are often comprised of multiple cells in series (for example, a 6 V lead-acid battery will have three cells). Within a battery's individual cells, the anode and cathode are physically separated, but surrounded by the electrolyte.

These components are housed in a plastic case, with accessible negative and positive terminals or posts. The negative terminal functions as the anode during discharge, while the positive terminal is the cathode. In a lead-acid battery, for example, the anode is a lead plate and the cathode is a lead-dioxide plate. A sulfuric acid and water solution is the electrolyte.

Inside a Flooded Lead-Acid Battery

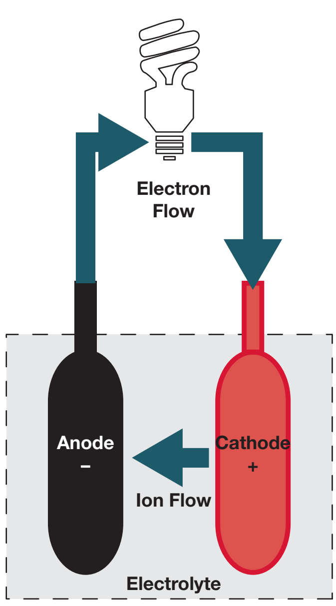
An electrochemical reaction takes place when there is a reason for electrons to move. Connecting a load (a light bulb, for instance) to a battery completes the circuit causing the electrochemical reaction to take place by "pulling" electrons out of storage. The resulting reaction moves electrons from the negative anode through the bulb, illuminating it. The electrons continue through the circuit to the positively charged cathode. The electrolyte completes the circuit by allowing a path for negatively charged ions to move back to the anode. As the cell discharges, lead sulfate forms on both plates and the ratio of water to sulfuric acid increases in the electrolytic solution, thus depleting the storage in the battery.

In recharging, the reverse reaction takes place. The positive terminal now gives up electrons and functions as the anode, while the negative terminal accepts electrons as the cathode. Like all energy transformations, there are losses in the conversion process (chemical to electrical and back again). While batteries are charging or discharging, some heat may be released. The lead-acid battery charging process also releases hydrogen gas.

A disposable, non-rechargeable battery does not need input to produce electricity as it comes in a fully charged state. Eventually, the battery and its electrolyte will exhaust its capacity to move ions.

—Erika Weliczko

Battery Cell



When a battery cell is discharging, electrons flow from the negative terminal, through the load, back to the positive terminal.

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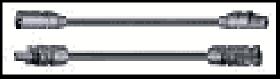

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